THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE III. VOL. IX.

No. III.—MARCH, 1892.

ORIGINAL ARTICLES.

I.—The Coniston Limestone Series.

By J. E. Marr, M.A., F.R.S., Sec.G.S.

(PLATE III.)

IT has long been known that the Coniston Limestone Series of the English Lake District and surrounding areas is separable into minor divisions. As a knowledge of these will prove useful in settling the question as to the exact relation between the Coniston Limestone beds and the underlying rocks, no apology seems needed for giving a detailed account of the rocks of this series.

The literature of the subject is extensive, but we fortunately possess an excellent bibliography of works referring to the geology of the Lake District, in the appendix supplied by Mr. Whitaker to the late Mr. Ward's Memoir on the Geology of the Northern Half of the English Lake District.

The main outcrop of the Coniston Limestone, as well known, is situated in a line running across the southern half of the district between Shap Wells and Millom, and here the series is succeeded by the Stockdale shales, and underlain by different members of the Borrodale Volcanic Series. Outlying patches occur in the Cross Fell area, the Sedbergh and Ingleton districts, and probably also in the extreme north of the Lake region.

§ 1. *Classification of the Beds.*

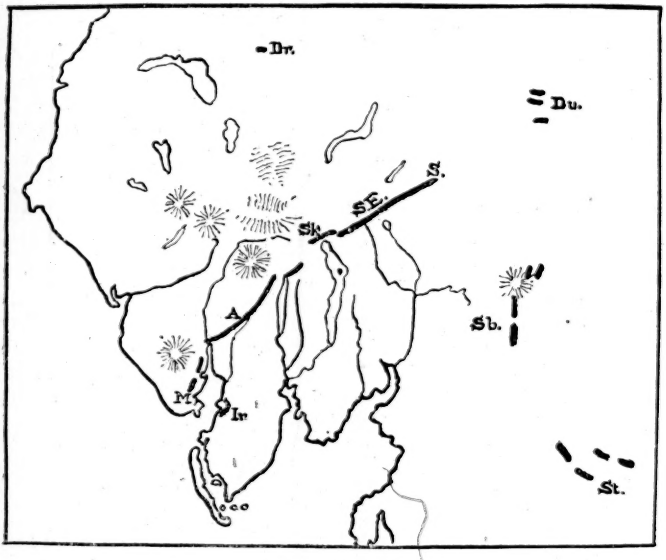
Leaving out of consideration the doubtful beds immediately succeeding the rhyolites of Melmerby (cf. Nicholson and Marr, Q.J.G.S. vol. xlvii. p. 509), and which may possibly form the summit of the Llandeilo Series, the strata which form the subject of this communication belong to the Bala or Caradoc Series, and representatives of the whole of this period are probably present in the north of England. They may be classified as follows:—

Coniston Limestone Series.	Ashgill Group	Ashgill Shales, 50 feet. *Staurocephalus* Limestone, 5 feet.
	Sleddale Group	Applethwaite Beds, 100 feet. Conglomerate, 10 feet. Stile End Beds, 50 feet, with Yarlside Rhyolites above.
	Roman Fell Group ...	*Corona* Beds, 100 feet.

The figures indicate only approximate average thicknesses. The three groups are readily distinguishable by the characters of their

faunas, that of the lowest group (Roman Fell), and of the highest (Ashgill), being quite different from that of the Sleddale group, which latter has yielded the greater number of fossils recorded in the Coniston Limestone lists hitherto published, though a few species belonging to the other two groups have been incorporated into these lists.

Outline-Map of the English Lake-District.



EXPLANATION OF MAP.

Scale 0 10 20 *Miles.*

Dr = Drygill.	SE = Stile End.
Ir = Ireleth.	S = Shap.
M = Millom	Du = Dufton.
A = Ashgill.	Sb = Sedbergh.
Sk = Skelgill.	St = Settle.

§ 2. *Detailed Description of the Sections.*—The fossils of the lowest (Roman Fell Group) have hitherto been detected only in the area of the Cross Fell Inlier, and the beds containing them have been recently described by Prof. Nicholson and myself in the paper referred to above. The thickness of the beds varies, and is difficult to measure owing to the disturbances which the rocks have undergone; but the greatest thickness probably does not exceed two hundred feet. The beds consist of ashes, ashy shales, and nodular black limestones, the latter often composed almost exclusively of the tests of *Beyrichia*. The table of fossils appended to this paper contains a list of the known forms from the beds of this group.

The other groups are well displayed in the tract of country between Shap Wells and Millom, and I propose to consider this tract first, commencing at the east end.

The most easterly section has been lately described (Harker and Marr, Q.J.G.S. vol. xlvii. p. 272). I would point out here that the limestone referred to the Stile End beds in that description may possibly be a member of the Roman Fell Group.

A considerable mass of fossiliferous ashy beds underlies the conglomerate near the Spa Well, and this mass may possibly represent the Stile End beds (the Yarlside rhyolite being here absent). The limestone above the waterfall at the head of the plantation presents lithologically a closer resemblance to the limestones of the Roman Fell Group than to the less pure limestones of the Stile End Group; but as no fossils have hitherto been recorded therein, the point must remain doubtful.

The lower limestone of the Wasdale Head section (Q.J.G.S. vol. xlvii. p. 271) is however, without doubt, the representative of that of Stile End, and lies immediately below the Yarlside rhyolite.

The section in Stockdale Beck is also given in our paper upon the Shap granite (p. 270). I would add a few words to the description given in that paper.

The Stile End Series is, as represented in our section, faulted against the rock of the underlying volcanic group. The evidence for this fault we hope to present in a future paper.

Above the nodular upper surface of the Yarlside rhyolite a thin band of ash is devoloped in Stockdale Beck.

The main mass of the conglomerate above this consists of subangular fragments chiefly of rhyolite, embedded in a slightly calcareous ashy matrix. The highest part of the conglomerate (well seen in Browgill) differs from this. It contains only a few pebbles which are mostly well-rounded, embedded in a tolerably fine calcareous matrix, and it passes up into the limestone of the Applethwaite Series, and is only separated from this series in the present communication on account of its importance as an easily recognizable horizon. The Ashgill Group is faulted out in Stockdale, but is seen in Browgill below the zone of *Diplograptus acuminatus*.

Few fossils have been obtained from the beds of this section; though fossils are abundant, they are indifferently preserved.

Crossing the valley of Long Sleddale, we find the Coniston Limestone Series well seen on the hills between that valley and Kentmere, especially near the farm of Stile End.

The Stile End beds are here quarried, and consist of grey-green calcareous ashes, weathering yellow, and containing abundant fossils, though these are badly preserved. We have identified:—

Lindstræmia subduplicata, M'Coy.
Phacops, cf. *Eichwaldi*, Schmidt.
Orthis vespertilio, Sow.
—— *calligramma*, Dalen.

This list, meagre as it is, indicates the close palæontological

relationship of the fauna of this series to that of the overlying Applethwaite Series.

The last exposure of the Yarlside rhyolite to the west occurs on the moorland above the Stile End beds, and in sections lying further west, the Applethwaite and Stile End beds are separated only by the conglomerate. The conglomerate has not been detected in the Stile End section, but the Applethwaite beds consist, as usual, of ashy calcareous shales, with bands and nodules of impure limestone. In the course of a small stream flowing towards Sleddale, and a little below the watershed, the *Staurocephalus* Limestone is seen faulted against the Skelgill beds of the Stockdale Shales, so that the Ashgill Shales are here cut out.

Many exposures of the Coniston Limestone Series are seen in the small valley running from the Garbourn Pass to Kentmere, occupied by the stream known as Hall Gill, and they contain abundant fossils, but the ground is much faulted, and it is difficult to make out the subdivisions.

On Applethwaite Common, also, the conglomerate has not been detected, and consequently it is impossible to assert positively that the representatives of the Stile End Group are present The Ashgill beds are found here, but their relationship to the Applethwaite series is not clearly shown. The beds of the latter series, as is well known, here contain abundant fossils. The highest beds of this series consist here of fairly pure limestones.

We now arrive at the important sections of the tract of country lying between Troutbeck and Windermere, the principal one being developed in Skelgill Beck and its tributaries.

Here, again, the conglomerate has not been seen, so that, although the beds seen in a quarry north-east of the 'Upper Bridge' over this stream strongly resemble the Stile End Beds, I am not prepared to assert that they belong to that series rather than to the Applethwaite series.

The beds of the Applethwaite Series consist mainly of calcareous, very fossiliferous, shales, with limestone bands, but a feature is here clearly seen, which probably characterizes also this series in the more obscure sections to the east. I refer to the existence of a white horny limestone at the very summit of the series. This is seen in the stream at the Upper Bridge, and the *Staurocephalus* limestone reposes directly upon it. No fossils have been extracted from this bed, but a number of large *Orthocerata* are seen in cross section in the bed of the beck. Such *Orthocerata* occur at Keisley, and it is possible that the Keisley limestone, which contains on the whole the fauna of the Applethwaite Limestone, along with some forms which are not known to occur nearer than the Chair of Kildare, is the highest subdivision of the Applethwaite Series. I wish to discuss this point at some length, because an important physical problem is connected with it. A similar limestone is found in Swindale Beck in the Cross Fell area, and was referred by Prof. Nicholson and myself to the *Staurocephalus* Limestone, on account of the occurrence of the fauna of that limestone in the associated

calcareous shales. These shales, however, occur above the main mass of the Swindale Limestone, and on a re-examination of our specimens, I am inclined to think that the lower and purer part of the limestone of that beck, which contains large *Orthocerata*, like those of Skelgill, along with *Illænus Bowmanni*, may have to be separated from the upper part which has the true *Staurocephalus* Limestone fauna, and correlated with the Keisley Limestone; (a similar limestone occurs below the *Staurocephalus*-beds of Billy's Beck). If this be the case, the difficulty connected with the Keisley Limestone would vanish. It would occur under two conditions in the Cross Fell area, first, as a coarsely-crystalline very fossiliferous rock; secondly, as a horny limestone in which the fossils are mainly destroyed. Without offering here an explanation of the frequent occurrence side by side of these two conditions of a calcareous deposit, I may point out that they are very frequently found in disturbed regions. I would cite in our own country the Devonian rocks of the neighbourhood of Torquay, where the two varieties are found in the same quarry, also the "Knolls" described by Mr. Tiddeman (Report International Geological Congress of 1888, p. 319), which are found only amongst the rocks south of the Craven Fault, where there are evidences of great disturbance, and not in the nearly horizontal rocks to the north of the fault. Abroad, a similar case occurs in Bohemia in the Konieprus Limestone (F. f. 2). This limestone is generally a thin, horny, nearly unfossiliferous limestone, but in the "Knoll" of Konieprus, and Mnienian, we find the two varieties side by side. The same may be said of the *Leptæna* Limestone and Klingkalk of Dalecarlia (cf. Nathorst, Aft. ur Fören. i Stockholm Geol. Förhandl. No. 93, Bd. vii. p. 559), and the Devonian Limestone of the Ardennes.

It is not needful to discuss the origin of the nodular masses of crystalline limestone in this place. The cases cited show that the occurrence of the horny and crystalline conditions of the same limestone in immediate proximity is a common event, and therefore, whatsoever be the true explanation, there is nothing anomalous in referring the Keisley Limestone to the Applethwaite Group, though, as stated in the discussion on the paper by Prof. Nicholson and myself on the Cross Fell area, we only refer the Keisley Limestone and the Dufton Shales (which latter contain the ordinary Applethwaite fauna) to the same subdivision of the Coniston Limestone Series. If the suggestion thrown out above should prove to be correct, a further division of the Applethwaite Group may be made into a lower stage characterized by the ordinary Applethwaite fauna, and an upper stage characterized by the fauna of Keisley and the Chair of Kildare. This will probably be finally settled when the Irish beds are re-examined, and in the meantime I include the Keisley fossils and those of the other Applethwaite beds in one list.

The *Staurocephalus* Limestone of Skelgill is succeeded at the Upper Bridge by the Ashgill Shales, which are seen in a very fossiliferous condition on a small knoll by the roadside close to the bridge. The *Staurocephalus* Limestone is not very fossiliferous in

Skelgill; but on the moorland between this beck and Nanny Lane it has yielded a large number of fossils, especially *Cystideans*.

On the west side of Windermere an important development of the Coniston Limestone Series is seen in the neighbourhood of Sunny Brow. On Limestone Hill, to the west of Sunny Brow, a fell-road exposes an ashy calcareous grit with many casts of *Lindstræmia*, faulted against the *Dimorphograptus* zone of the Skelgill beds. On the hill to the east of the road, and also in Cross Intake, normal Applethwaite Limestone is seen, with many corals. Although the conglomerate has not been detected here, the character of the ashy grit leaves little doubt that we are here dealing with the representative of the Stile End Beds, and this was the view taken by Professors Harkness and Nicholson in 1866 (Q.J.G.S. vol. xxiii. p. 482).

On the high moorland south-west of Coniston Lake, the Coniston Limestone Series is seen in numerous exposures, and the Applethwaite Series is extremely fossiliferous. Along this tract, as in the case of the Stockdale Shales, the cleavage is much stronger than in the district already traversed. The best section of the lower part of the series is shown at High Pike Haw, near the head of Appletreeworth Beck, whilst the upper portion is excellently displayed in Ashgill Quarry.

At High Pike Haw the discordance of strike between the Coniston Limestone Series and the underlying Borrodale volcanic rocks is excellently exhibited, as shown on the map of the Geological Survey. The lowest rock having the strike of the Coniston Limestone Series is a purple breccia associated with green ash. Above this are bedded ashy grits and conglomeratic beds, succeeded by a fossiliferous calcareous ash, strongly resembling the Stile End Beds. That it is actually referable to these beds is shown by the existence of a calcareous conglomerate above it, occupying the same position as at Shap and Stockdale. The conglomerate is succeeded by the Applethwaite Beds, which have a well-marked fine ash at the summit. The *Staurocephalus* Limestone is not seen here, though the Ashgill Shales come on above the Applethwaite group.

In Ashgill Quarry, the *Staurocephalus* Limestone is seen in the north-west corner, brought against the Skelgill Beds by a cross-fault. The Ashgill Shales form the main mass of the quarry, and are succeeded by the Skelgill Beds, in true sequence, at the top of the quarry-cliff. The relationship between the *Staurocephalus* Limestone and the Ashgill Shales above and Applethwaite Beds below, is also seen at one or two points in the course of Appletreeworth Beck.

The section at Millom generally resembles that at High Pike Haw. In Waterblean Quarries the lowest rock seen is a rhyolite of the Borrodale Series. Upon it rest green ashes and breccia, and then a purple breccia, as at High Pike Haw, but the fossiliferous Stile End Beds do not appear to be exposed in this quarry, although a remarkable development of beds, apparently referable to this stage, occurs in Millom Park, north of Beck Quarry, and striking so as

to pass under the limestone of that quarry, and above the purple breccia which occurs to the west of this. These Millom Park Beds consist of ashy grits, and one pure quartzose grit, all crowded with fossils. At the base of the Applethwaite Limestone, both at Waterblean and in a small quarry south-west of Beck Quarry, we find the conglomerate, consisting of a calcareous ashy matrix, with the usual subangular fragments.

In Beck Quarry calcareous shales of ordinary character yielded the tail of a *Phacops* (*Chasmops*), but the greater part of this quarry, and of Waterblean Quarry, is excavated in a mass of crystalline limestone, white, except where stained pink by hæmatite, greatly disturbed, and resembling the Keisley Limestone in all particulars, save that it has unfortunately yielded no fossils hitherto.

On the east side of the Duddon Estuary, some interesting sections are displayed in the neighbourhood of Dalton and Ireleth. The rocks here are greatly disturbed. The lowest beds yet discovered belong to the Applethwaite Limestone subdivision, and rest sometimes on the Borrodale Beds, as near Ireleth, and to the west of High Haulme, sometimes upon the Skiddaw Slates, as in the neighbourhood of Crag Wood, west of High Haulme. Near Crag Wood the limestone is usually crystalline, as at Millom, and occurs in a series of remarkable knolls, surrounded by low ground, apparently occupied by shales. At the top of the Applethwaite Limestone we meet with a rock looking like a coarse breccia, succeeded by the Ashgill Group, so that it occupies the same position as the highest ash at High Pike Haw. It is seen in many exposures near High Haulme Farm, and its position is inserted on the Geological Survey Map. Its exact nature is doubtful. Normal Ashgill shales are found above it, and are seen in many exposures to the north of this, as far as Ireleth. Here the interesting section at Rebecca Hill shows the Ashgill Shales, containing in one place a thin band or nodule of much-crushed limestone, succeeded by a fossiliferous ashy deposit (also mapped by the Geological Surveyors), and separating the Ashgill Shales from the Stockdale Shales. That it appertains to the former is indicated by the interstratification of thin bands of shale, quite indistinguishable from the ordinary Ashgill Shales below. It would seem, therefore, that we have, in the Lake country, indications of volcanic activity throughout the whole period represented by the Coniston Limestone Series. Before leaving this part of the district, I may observe that the limestone of Tottlebank, south of the foot of Coniston Lake, which has sometimes been taken to be a continuation of the Coniston Limestone of the Ireleth region, is really on a much higher horizon, as indicated by the Geological Survey Map, and indeed belongs to the Lower Ludlow beds.

Turning to the outlying outcrops of the Coniston Limestone Series, I may revert to the Cross Fell area merely to remark that the Dufton Shales are the equivalents of the Sleddale Group as a whole, and that no conglomerate is found to separate them into Stile End and Applethwaite subdivisions, as has been done along the main outcrop.

Further details concerning the beds of this area will be found in the paper by Professor Nicholson and myself which has been alluded to previously.

The beds of the Sedbergh District are generally comparable with those of the Cross Fell inlier, *i.e.* the Sleddale Group assumes the facies of the Dufton Shales more closely than that of the region around Windermere and Coniston. The Calcareous Shales of Sally Beck south of Ravenstonedale are closely comparable with the Dufton Shales of Cross Fell. The *Staurocephalus* Limestone has not yet been detected in these regions, though the Ashgill Shales are developed in force; indeed the characteristic Brachiopod of these shales—*Strophomena siluriana*, Dav.—is figured in Mr. Davidson's Monograph from specimens obtained at Fairy Gill. In the centre of the Ashgill Shales a very calcareous grit is found (cf. Marr and Nicholson, Q.J.G.S. vol. xliv. p. 700), as seen at Backside Beck.[1]

The rocks of the Settle district have been referred to by me in a paper published in this MAGAZINE (Dec. III. Vol. IV. p. 35). The Applethwaite Group has the facies of the Dufton Shales, though a band of ashes is interstratified with the calcareous shales. The *Staurocephalus* Limestone has not been detected, though the Ashgill Shales are seen in the stream south of Wharfe, for I have found fossils of this age in the beds numbered "4. Blue, flaggy Brachiopod shales," in the paper referred to. Though the relationship of the Coniston Limestone Series to the representatives of the Stockdale Shales is perfectly clear in this neighbourhood, the true relations of the former to the Ingleton Green Slates is by no means clear. We have seen that in the central part of the Lake District the Coniston Limestone rests sometimes on the Skiddaw Slates, and not on the Borrodale rocks. Now the only reason why the Ingleton Green Slates have been referred to the Borrodale Series is because they are made up of volcanic detritus, and are immediately succeeded by the Coniston Limestone Series. As the latter fact does not prove their age, we can only point to the occurrence of volcanic detritus as a proof of the correctness of the correlation. The lithological resemblances, however, are very slight, and the volcanic detritus may be derived from rocks of any age. I am inclined to think that these Ingleton Green Slates may be older than any other beds hitherto recorded from the English Lake District, for there are grave difficulties in the way of correlating them with the Borrodale Volcanic Series.

[1] Since writing the above I have received the Survey Memoir of Quarter-Sheet 97 N.W. The contemporaneous volcanic series of Backside Beck and Wandale occurs at a higher horizon than that of any of the contemporaneous lavas hitherto detected in other parts of the district, with the possible exception of that running from Kentmere to Shap, and separating the Stile End Limestone from the Applethwaite Beds. It seems to occur high up in the Sleddale Group, and it will be remembered that contemporaneous volcanic ashes are found at the very summit of this group in the Coniston area. Mr. Strahan records the occurrence of a grit in the Ashgill Shales on a position corresponding to that of the above-mentioned calcareous grit, both in Taiths Gill and Birk's Field Gill.

The thickness of the Ashgill Shales recorded in Fairy Gill is exceptional.

The last area to which I have to refer is situated in the extreme north of the Lake District. Here a group of fossiliferous beds has been described by Professor Nicholson and myself as occurring at Drygill in the Caldbeck Fells (GEOL. MAG. Dec. III. Vol. IV. p. 339). We were led "to refer the Drygill Shales to about the horizon of the Llandeilo Limestone, or to a slightly higher point in the series." Since then I have re-examined the fossils, and believe that two of them were wrongly identified (I may remark that I alone was responsible for this error). The *Calymene* recorded is more like *senaria* than *cambrensis*, and I cannot distinguish the *Trinucleus* from *T. concentricus*. The other fossils recorded are normal Caradoc fossils, and indeed, looking at the former list dispassionately, one would say that there was a preponderance of Caradoc forms, so that our reference of the deposits to the Llandeilo Series was no doubt influenced by its proximity to the Skiddaw Slates, for we remark that "they agree most nearly with the Dufton Shales as regards their fauna" . . . . though "from their general position between the Skiddaw Slates on the one hand and the lavas and ashes ('Eycott Series') of the Caldbeck Fells on the other hand, we should be led to conclude that they occupy a place low down in the latter series." As we have elsewhere seen that the Coniston Limestone is brought into contact with the Skiddaw Slates, the occurrence of Bala fossils near the Skiddaw Slates is not necessarily to be taken as an indication of the low position of the Drygill Shales, and looking at the fossils as a whole, I am disposed to refer the Drygill Shales to the Coniston Limestone Series, and not even to the lowest position of this, as the fauna is more closely comparable with that of the Dufton Shales than with that of the underlying *Corona* Beds.

Another argument in favour of the occurrence of a Coniston Limestone fauna on the north side of the district is the existence of *Cybele* near Cockermouth. Mr. Etheridge describes under the name of *Cybele ovata* a fossil found by Mr. Birkett, at Sandy Beck, near Wood (cf. Memoir by Rev. J. C. Ward, "The Geology of the Northern Part of the English Lake District," Appendix A, p. 112). Unfortunately, as I learn from Mr. Postlethwaite, the specimen was not found *in situ*, but occurred in a pebble; still, as this can hardly have been brought from the south side of the district, it probably indicates the existence of rocks with *Cybele* on the north side. Now this genus is not found in Britain below the Bala rocks, though it occurs at a lower horizon in Russia and Sweden. I have examined Mr. Birkett's specimen (now in the Keswick Museum), and it is very near to, if not identical with, *Cybele Loveni*, Linns., a common Coniston Limestone form.

§ 3. *Results of the Examination of the Series.*

The various equivalents of the Coniston Limestone Series have been discussed by myself and others in earlier communications, and it is only necessary here to give a general summary of the conclusions.

In the description of the Cross Fell Inlier by Professor Nicholson

and myself, we compared the Roman Fell Beds with the *Beyrichia* Limestone of Scandinavia and the Trenton Limestone of North America, and suggested their correspondence with the Ardwell Beds of the Girvan area. The peculiar fauna will probably be discovered elsewhere, and should be searched for amongst the shales below the Bala Limestone of North Wales, and among the fossiliferous beds of Tyrone.

The well-known fauna of the Sleddale Group[1] has been so frequently and successfully compared with the similar fauna of the Bala Limestone, and its equivalents in the British and foreign Lower Palæozoic areas, that it is unnecessary to discuss the identity in this place, for it is now generally recognized. The relationship of the Dufton Shales to the *Trinucleus* Shales on the one hand, and the normal Sleddale Beds on the other, has also been commented on in a previous communication. The very abrupt change from the Lake District type of the Sleddale Group to the Cross Fell type in the short interval occupied by the newer beds of the Eden Valley, is a point that requires notice. I have already remarked on the likeness of the Keisley Limestone to that of the Chair of Kildare. A re-examination of the Bala Beds of Kildare and Tyrone is very desirable, as several stratigraphical horizons appear to be represented there, judging from the fossils which have been obtained.

The equivalents of the *Staurocephalus* Limestone occur in many parts of Britain, as well as in Scandinavia. Indeed, it is at first sight surprising to find how constant are the lithological characters of this green argillaceous limestone, when we remember that it is seldom more than a few feet in thickness. It retains its peculiar character in the south of Scotland (the "Starfish-bed), North Wales (*Rhiwlas* Limestone), Pembrokeshire (*Staurocephalus* Limestone), Ireland, and Scandinavia.

An examination of the fauna fully accounts for this constancy of character. Though it contains many species common to the overlying Ashgill Shales, there is a marked change betwixt the organisms of this limestone and those of the underlying Sleddale Group, and very few species are common to the two. Insignificant, therefore, as the thickness of this deposit is, the time taken for its

[1] It may be remarked that sufficient proof has not been offered as to the distinctness of the Stile End Beds from the *Corona* Beds of the Cross Fell area. The somewhat meagre list of Stile End fossils previously given does not bring out the marked contrast between these beds and those of the Roman Fell Group. Not only is the peculiar fauna of the *Corona* Beds entirely absent from the Stile End deposit (and fossils, though ill-preserved and belonging to few species, are very abundant at Stile End), but the Stile End rocks are crowded with casts of *Lindstræmia*, both in the region where the Yarlside rhyolite separates them from the Applethwaite Beds, and in the region further west. No *Lindstræmia* has yet been detected in the Roman Fell Beds. In the neighbourhood of Coniston the Stile End Beds contain numerous fossils, which, as is usual with the beds of this series, are preserved as casts only, but fragments of several fossils generically identical with those of the Applethwaite Beds are easily discoverable, and, as far as one can judge, they are also specifically identical. Though it is just possible, therefore, that these Stile End Beds are actually representatives of the Roman Fell Group, all the evidence points to their being newer.

accumulation was probably very great, and its characteristic organisms had time to become widely dispersed. The *Staurocephalus* fauna is far from being fully described, and few deposits would better repay a close examination by a local geologist. The most fossiliferous localities yet discovered in the north of England are the west corner of Ashgill Quarry, the moorland between Skelgill and Nanny Lane, Troutbeck, and, in the Cross Fell area, Swindale Beck and Billy's Beck. The Echinoderms and Crustacea of the bed are particularly remarkable.

The overlying Ashgill Shales and their equivalents are fairly well known in those regions where there is a passage betwixt the Ordovician and Silurian strata. In Scotland we have similar shales above the starfish-bed in Lady Burn. In North Wales blue shales apparently referable to this horizon occur between the Bala Limestone and the Hirnant Limestone. In South Wales the Redhill beds contain a similar fauna, and occupy the same position. In Sweden the resemblance of the shales lying between the *Staurocephalus* Limestone and the representatives of the Stockdale Shales to our Ashgill Shales is very noticeable.

In North Wales the Hirnant Limestone is generally placed at the summit of the Ordovician beds, and Mr. T. Roberts and myself have also placed the Slade Beds of South Wales in a similar position. In Scandinavia, Tullberg assigns the lowest Graptolite-bearing stratum above the beds containing normal Bala fossils to the Ordovician system, on account of the absence of *Monograptus*. As it is succeeded by beds containing *Dimorphograptus*, it is probably the equivalent of the zone of *Diplograptus acuminatus* of the Birkhill (Skelgill) shales, and the same may be true of the Hirnant Limestone and the Slade Beds. The truth is that where we have an unbroken succession between Ordovician and Silurian rocks, the exact line of demarcation must be purely conventional.

In the table[1] (Plate III.) showing the variations of the different members of the Coniston Limestone Series, no attempt is made to give an exact representation of their actual thicknesses in various localities, for in the case of beds which have been so disturbed, such thicknesses, as taken by measurement on the ground, would probably be incorrect. Nor is this a matter of much importance in a case where volcanic outbursts are clearly seen to determine to a very large extent the changes of thickness, when the beds are traced along the outcrop. It is clear that in such cases, the position of former continental masses cannot be ascertained from a study of the direction of thinning out of the beds. The Ashgill Shales, however, do not show any great amount of volcanic material, but appear to be normal sediments. If the thickness assigned to these beds in Fairygill, in the Sedbergh district, be an approximation to their original thickness, this would show an expansion of these beds when traced eastwards, and this agrees with the observations made by Professor

[1] In this table, whilst the lava-flows and more prominent ashes are inserted, no attempt is made to indicate the finer volcanic material mixed with the Calcareous muds of many of the beds of the Roman Fell and Sleddale Groups.

Nicholson and myself in the case of the Stockdale Shales, which furnish much more precise data for accurate measurement. It is possible, therefore, that land lay to the south-east of the Lake District at the end of Ordovician and commencement of Silurian times, and this is supported by an examination of higher Silurian strata. The consideration of the beds above the Stockdale Shales must, however, be reserved for a future occasion.

§ 4. *Fossils of the Coniston Limestone Series.*

I. Roman Fell Group.

The smaller Crustacea are omitted in this list. They require revision.

Conchicolites gregarius, Nich.	Pusgill ; Roman Fell.
Ateleocystites, sp.	Roman Fell.
Homalonotus rudis, Salt.	Roman Fell.
Lingula tenuigranulata, M'Coy ...	Pusgill ; Roman Fell ; Swindale.
Strophomena grandis, Sow.	Swindale ; Pusgill.
Orthis testudinaria, Dalm.	Roman Fell.
Trematis corona, Salt.	Pusgill ; Harthwaite Beck ; Roman Fell.
Ambonychia gryphus, Portl.	Pusgill ; Roman Fell.
Bellerophon acutus, Sow.	Roman Fell.
—— *bilobatus*, Sow.	Pusgill ; Roman Fell.
Actinoceras pusgillensis, Foord... ...	Roman Fell.
Cyrtoceras?...	Roman Fell.

II. Sleddale Group.

The fossils from the Dufton Shales, and Keisley Limestone are included in the list. They will be recognized from the localities attached. The Corals are omitted, as the Coniston Limestone Corals are now being examined by Prof. Nicholson. Polyzoa also want revising.

Dicellograptus complanatus, Lapw. ...	Swindale.
—— *anceps*, Nich.	Norber ; Skelgill ?
Diplograptus socialis, Lapw. ?	Swindale.
—— *truncatus*, Lapw.	Hurning Lane, Dufton ; Norber.
Tentaculites anglicus, Salt.	Troutbeck ; Coniston ; Norber.
Ateleocystites, sp.	Norber ; Wharfe.
Acidaspis, n.sp.	Pusgill ; Applethwaite.
Amphion, n.sp.	Troutbeck.
Ampyx tetragonus, Ang.	Pusgill ; Billy's Beck.
—— *tumidus*, Forbes	Keisley.
Beyrichia complicata, Salt....	Applethwaite ; Coniston.
Calymene Blumenbachii, Brong. ... var. *Caractaci*, Salt.	Coniston ; above Rother Bridge.
—— *senaria*, Conr.	Horton ; High Haulme ; Coniston ; Applethwaite ; Swindale.
Cheirurus bimucronatus, Murch. ...	near Dent ; Keisley.
—— *cancrurus*, Salt....	Keisley.
—— *clavifrons*, Dalm. ?	Keisley.
Cybele Loveni, Linnrs.	Applethwaite ; Dufton ; Norber.
—— *verrucosa*, Dalm.	Ravenstonedale ; Helm Gill ; Swindale ; Pusgill ; Applethwaite ; Coniston.
Cyphaspis, cf. *triradiatus*, Törnq. ...	Keisley.
Cyphoniscus socialis, Salt....	Keisley.
Dindymene, n.sp.	Norber.
Encrinurus multiplicatus, Salt... ...	Barking ; Dent.
—— *multisegmentatus*, Portl. ? ...	Sunny Brow.
Harpes Doranni, Portl.	Coniston.
Homalonotus punctillosus, Törnq. ...	Keisley.
—— *Sedgwicki*, Salt.	Ravenstonedale.
Illænus Bowmanni, Salt.	Coniston ; Applethwaite ; Swindale.

Illænus cf. *conifrons*, Billings	Keisley.
—— *Davisii*, Salt.	Troutbeck; Wharfe.
—— *Rosenbergi*, Eichw.	Long Sleddale; Troutbeck; Sunny Brow.
Lichas laxatus, M'Coy	Pusgill; Keisley.
—— *laciniatus*, Dalm.	Coniston; Keisley.
Phacops Brongniartii, Portl.	Applethwaite; Coniston; Swindale; Backside Beck.
—— cf. *brevispina*, Schmidt	Coniston.
—— cf. *Eichwaldi*, Schmidt	Coniston; Applethwaite; Stile End.
—— (*Pterygometopus*) sp....	Norber.
Phillipsinella parabola, Barr.	Norber.
Primitia strangulata, Salt.	Applethwaite; Coniston.
Remopleurides Colbii, Portl.	Swindale; Applethwaite.
—— cf. *longicostatus*, Portl.	Keisley.
Sphærexochus boops, Salt....	Applethwaite; Coniston.
—— *calvus*, M'Coy	Keisley.
Trinucleus concentricus, Eaton	Pusgill. [Norber.
—— *seticornis*, His.	Applethwaite; Pusgill; Hurning Lane;
Turrilepas, sp.	Norber.
Youngia (Linnrs. non R. Jones) *trispinosa*, Nich. and Eth. jun.	Pusgill; Hurning Lane.
Atrypa expansa, Linnrs.	Keisley.
Leptæna transversalis, Dalm.	Coniston; Hilton Beck; Norber; Wharfe.
Lingula ovata, M'Coy	Coniston; Applethwaite.
Orthis Actoniæ, Sow.	High Haulme; Coniston; Applethwaite; Helm Gill; Keisley.
—— *bidens*, Salt., MS.	Helm Gill.
—— *biforata*, Schloth.	Ravenstonedale; Helm Gill; Troutbeck.
—— *calligramma*, Dalm....	Helm Gill; Troutbeck; Stile End.
—— *elegantula*, Dalm.	High Haulme; Helm Gill; Troutbeck.
—— *flabellulum*, Sow.	Applethwaite; Skelgill.
—— *insularis*, Eich....	Coniston; Troutbeck.
—— *porcata*, M'Coy...	High Haulme; Helm Gill; Troutbeck;
—— *spiriferoides*, M'Coy...	Troutbeck. [Keisley,
—— *testudinaria*, Dalm.	Pusgill; Harthwaite Beck; Keisley.
—— *vespertilio*, Sow.	Troutbeck; Coniston; Stile End; Dufton;
Strophomena corrugatella, Dav. ...	Keisley. [Keisley.
—— *deltoidea*, Conr....	Keisley.
—— *expansa*, Sow.	Keisley; Harthwaite Beck.
—— *pecten*, Linn.	Ravenstonedale; Troutbeck.
—— *rhomboidalis*, Wilck.	Helm Gill; Troutbeck; Coniston.
Loxonema obscura, Portl.	Keisley.
Cyrtoceras sonax, Salt.	Helm Gill.
Orthoceras, cf. *elongato-cinctum*, Portl.	Keisley.
Orthoceras velatum, Blake...	?
Trochoceras cornu-arietis, Sow. ...	Troutbeck; Coniston.

IIIa. Staurocephalus Limestone.

Echinosphærites arachnoideus, Forbes	Swindale.
—— *balthicus*, Eichw.	Troutbeck.
—— *Davisii*, M'Coy...	Troutbeck.
—— *mammosus*, Salt. MS. ?	Troutbeck.
Agnostus trinodus, Salt. ?...	Troutbeck.
Acidaspis	Swindale.
Calymene Blumenbachii, Brongn. ...	Ashgill.
Lichas laciniatus, Wahl.	Swindale.
Ogygia...	Ashgill.
Phacops apiculatus, Salt.	Ashgill; Troutbeck.
—— *eucentra*, Ang.	Ashgill; Troutbeck.
—— *Jukesii*, Salt.	Swindale.
Phillipsinella parabola, Barr.	Swindale; Troutbeck.
Staurocephalus globiceps, Portl. ...	Troutbeck; Billy's Beck; Swindale.

Turrilepas	Ashgill; Troutbeck; Swindale.
Skenidium, n.sp....	Billy's Beck.
Holopea	Troutbeck.
Orthoceras vagans, Salt.	Troutbeck.

IIIb. Ashgill Shales.

Cornulites	Skelgill; Backside Beck.
Myelodactylus ?	Backside Beck.
Glyptocrinus	Skelgill.
Ogygia	Troutbeck.
Phacops apiculatus, Salt.	Rebecca Hill; Troutbeck.
—— *eucentra*, Ang.	Ashgill; Troutbeck.
Phyllopora Hisingeri, M'Coy	Backside Beck.
Orthis actoniæ, Sow....	Skelgill.
—— *biforata*, Schlot.	Skelgill; Ashgill; Swindale; Backside Beck.
—— *calligramma*, Dalm.	Skelgill.
—— *elegantula*, Dalm.	Skelgill; Swindale.
—— *protensa*, Sow.	Skelgill; Ashgill; Swindale; Backside Beck.
—— *testudinaria*, Dalm.	Skelgill; Applethwaite.
—— *vespertilio*, Sow.	Skelgill.
Strophomena siluriana, Dav.	Troutbeck; Skelgill; Ashgill; Rebecca Hill; Swindale; Fairy Gill; Backside Beck.
Theca triangularis, Portl.	Skelgill.
Bellerophon	Ashgill.

II.—Remarks on the Formation of Landscape Marble.

By Horace B. Woodward, F.G.S.

THE Landscape Marble or Cotham Stone is one of the best known of our English ornamental rocks. Polished slabs of it may be seen in most museums; and there are fashioned out of it paper-weights, ring-stands, and other useful objects, which may be purchased on Clifton Down and elsewhere.

This stone came into notice when it was quarried, together with other beds, near Cotham House, on the northern side of Bristol; and it was described in considerable detail in 1754 by Edward Owen, who then gave it the name of "Cotham Stone."[1]

It is a hard, close-grained argillaceous limestone, which breaks with a fracture almost as conchoidal as that of flint; and it is characterized by dark arborescent markings which pervade the stone. These markings rise from a more or less stratified base, and terminate upwards in the wavy banded portion of the limestone, which varies from one to about nine inches in thickness. Thus when slabs, cut at right angles to the planes of bedding, are polished, there may often be discerned (with the aid of the imagination) a landscape with a prominent row of trees and bushes, with clouds above, and perhaps the semblance of water in the foreground.[2]

The lower surface of the limestone is even, though sometimes in small masses of the rock it is gently curved; the upper surface is corrugated, and the irregularities appear to correspond in many instances with the original planes of deposition, for thin layers that

[1] Observations on the Earths, Rocks, Stones, and Minerals, for some miles about Bristol, etc., 8vo. London.

[2] An illustration of the Landscape Marble was published in the Proc. Geol. Assoc. vol. i. p. 209.

coincide with the uneven surface may be split from the rock. In other instances the ridges on the surface are curiously interlaced, forming a kind of "rustic work" that is prized for rockeries. It seems likely that the upper surface of the stone is largely due to the shrunken state of the calcareous mud from which the Cotham Stone originated. So far as I know, wherever the crinkly surfaces and the arborescent markings are present, the limestone occurs in isolated and lenticular masses; and these are sometimes less than a foot across, sometimes three feet or more. Where the stone, or its equivalent, occurs as a fairly persistent layer, it maintains its compact character, it is banded and evenly bedded, but the arborescent markings are wanting.

While the Cotham Stone is present in a number of localities from Bristol to Uplyme in Devonshire,[1] yet in many sections exposed over that area it has not been recognized or but doubtfully identified, partly because of its impersistent nature, and partly because it may be represented by a layer without arborescent markings. This is the case also in the country north of Bristol.

It is interesting to find that this layer of limestone extends, even in interrupted masses, over so large an area, and it is noteworthy that wherever the characteristic Landscape Marble has been observed, it occupies a position in the Rhætic Beds, at or near the junction of the Black *Avicula-contorta* Shales with the overlying beds of White Lias. The limestone thus forms an horizon of some service to the geological surveyor, and it may be tracked across many a ploughed field between Bath and the Mendip Hills. The finest examples of the stone that I have seen, were opened up during the construction of the Midland Railway between Bath and Kelston.

To its stratigraphical position the Cotham Stone may in some measure owe its peculiar characters, occupying as it does an intermediate place between dark argillaceous sediments and almost pure calcareous mud. In some localities a few inches of dark clay may be found above the Stone, but usually it is overlaid directly by the pale marls and limestones of the White Lias. It marks a stage when this calcareous sediment was commingled with a slight amount of dark mud deposited in occasional films. Thus an ordinary banded limestone was produced in many places, as seen in the railway-cutting at Cossington, between Bridgewater and Edington, at Aust, and at Lassington near Gloucester. Beds of this character, although they exhibit no arborescent markings, are often spoken of as "Cotham Marble," because they occupy the same stratigraphical position.

Between this ordinary banded limestone and the distinctly arborescent types, all sorts of intermediate varieties may be found; but as most of these varieties are not 'ornamental,' they are regarded as unsuitable for polishing, and do not come much into notice. Occasionally in less compact rocks, where darker and lighter layers of material are present, arborescent markings may be found; this is the case in the '*Estheria*-bed,' which occurs in the upper part of the

[1] See Dr. Wright, Geol. Mag. 1864, p. 291.

Rhætic Beds at Garden Cliff, Westbury-on-Severn; and it is an exceedingly irregular and nodular limestone.

In other formations I have met with similar phenomena. In the Lower Purbeck Beds at Durlston Bay, near Swanage, there is a thin layer of limestone that presents the same corrugated and mammillated surface as the Cotham Stone, and it exhibits obscure arborescent markings. Again at Rounden Wood near Battle, a layer presenting like characters, occurs also in the Purbeck Beds. In the same district near Battle, there is a bed of more or less nodular limestone called the 'Cutlets,' and this sometimes possesses curious irregular bands of light and dark grey tints, that form a sort of intermediate stage between even banded limestone and Landscape Marble. There is a specimen of this rock in the Museum at Jermyn Street.

Another illustration I have met with in the Inferior Oolite of Charlcombe, near Bath, where there occurs a bed of compact brown limestone, banded at the base like the Cotham Stone, and becoming nodular (and in this case also somewhat concretionary) above; and this rock exhibits faint resemblances to arborescent markings.

For want of a better explanation I have elsewhere compared the arborescent markings in the Landscape Marble with the dendritic *infiltrations* of manganese-ore, etc., so commonly met with on the surfaces of rocks, whether along joints or bedding-planes.[1] I now think there is no particular connexion between the phenomena of *infiltration* and the production of the Landscape Marble.

The ferruginous infiltrations that produce irregular bands of colour throughout the mass of many rocks, present no close resemblance to the features of Landscape Marble. Some of the appearances met with in the fissile limestone known as 'Florentine Slate' and 'Ruin Marble,' are due to infiltrations of oxide of iron that permeated the stone probably after consolidation; while the rock itself, thus irregularly banded, was subsequently fractured, and portions of it shifted by minute faults that have given the sharp outlines to the "ruins."

It may be mentioned that other beds of limestone above the Cotham Stone, and as high as the 'Sun Bed,' which is locally the top layer of the White Lias, occasionally present irregular and corrugated surfaces, but these occur in homogeneous limestone, and no arborescent markings are exhibited. The fact indirectly lends support to the view that the arborescent markings of the Cotham Stone are contemporaneous and not due to subsequent infiltration.

There is no evidence to support the notion that gaseous emanations, such as might have arisen from the black mud of the *Avicula contorta* Shales, had anything to do with the formation of the Landscape Marbles. This notion was to a certain extent suggested by E. Owen, who thought the arborescent markings were produced by the escape of imprisoned air; but had such agents been at work the markings would not be confined to the nodular masses of rock, and they would extend upwards through the base of the limestone.

It appears to me that the arborescent markings were produced

[1] Geol. E. Somerset, etc. (Geol. Survey), p. 70; and Geol. England and Wales, ed. 2, p. 244.

during the consolidation of the stone, and more particularly by the shrinking of its upper portions. In this way, and while the mud was still in a more or less pasty condition, one or more of the dark films in the banded mass were disarranged and dispersed in arborescent form in the slowly setting rock. The features displayed in different specimens of the Landscape Marble suggest that sometimes an upper and sometimes a lower film of dark mud was dispersed. There are specimens likewise that exhibit a double landscape, one above the other. An example is figured by E. Owen (*op. cit.* pl. i. p. 163), and similar specimens are preserved in the Museum of Practical Geology. In these instances there seems evidence of a prior consolidation in the rock, followed by more calcareous mud, the whole ultimately coalescing to form one layer of limestone. It may be that the production of the isolated masses of rock with their irregular upper surfaces, was attended by some pause in the deposition of sediment, and by exposure of the layer to the sun's rays. There is no doubt that such circumstances took place during the Rhætic period; and the rolled lumps of contemporaneous limestone met with in the White Lias near Lyme Regis and near Harbury are suggestive of such exposure during the later stages of the period.[1] Thin veins of calc-spar occasionally penetrate the 'inferior kinds' of Landscape Marble, and these fill cracks that were perhaps the final result of consolidation: the mass of the stone being sometimes found in a minutely faulted condition.

Under the microscope the dark arborescent portions appear sharply defined from the main mass of the Cotham Stone, and some tiny dark portions are seen to be isolated. Mr. J. J. H. Teall, who kindly examined the rock, states that it is "mainly composed of extremely fine granular calcite, and that it contains a few very small grains of quartz. In the part which shows the characteristic markings there are patches of clear and sometimes coarse-grained crystalline calcite." These facts are not inconsistent with the view that the appearances are due to the partial intermixing of the dark and light layers of mud during consolidation, albeit attended by some crystallization of calcite.

The evidence here brought forward is essentially stratigraphical; but if the suggested explanation be true, it serves to indicate the kind of re-arrangement that may take place when a pasty sedimentary mass solidifies in a somewhat irregular manner.

It has been noticed that the upper surface of the Cotham Stone is generally corrugated, but that it is sometimes formed of branching or interlacing ridges. These latter may be connected with phenomena of segregation. The segregation and concentration of calcareous material is shown in the irregular and nodular character of some of the Lias limestones, and in other formations where cement-stones and septaria occur. Some nodules of "race" and ironstone exhibit mammillated surfaces, when there is no evidence of concretionary action such as would be indicated by the deposition of successive coats of mineral matter.

[1] Proc. Geol. Assoc. vol. xi. p. xxx.

The process of formation of the Landscape Marble seems to me to have been mainly mechanical, although, as might be expected, there is evidence also of chemical change. In attributing the corrugated surfaces to the shrinking of the calcareous mud, I may have appealed too strongly to mechanical causes, as apart from the obscure processes of segregation, or even of concretionary action.

The facts, however, show the connexion between the arborescent markings and the corrugated and lenticular masses of banded limestone; and they support the contention that the markings were produced by changes amid the variously tinted calcareous mud during its solidification.

III.—Note on the Composition and Structure of the Hirnant Limestone.

By L. W. Fulcher, B.Sc., F.C.S.

(PLATE IV.)

During the summer of 1890, Professor Cole and I, whilst geologising in North Wales, were led to examine the Hirnant Limestone. Since then the further examination in the laboratory of the specimens collected by myself have revealed some remarkable characteristics which, as they are as yet undescribed, I think are worthy of notice.

The specimens on which the following observations have been made were obtained from a small cutting opposite to the farm named Cwm-yr-aethnen, in the valley of the Hirnant, which descends towards Bala Lake. The limestone occurs here between two beds of fossiliferous slate. The exposure is very small, and being considerably overgrown, it was only by careful search that we succeeded in finding it. The Survey Memoir[1] mentions that an outcrop occurs at Trum-y-gwrageda, and also that loose blocks were found by Sedgwick at the Bwlch-y-groes; but after a careful search we failed to find it at either of these localities.

It is necessary for me to add here that I am greatly indebted to Prof. Cole for much valuable advice and criticism of the facts observed as well as for the loan of some material, and I hereby tender him my best thanks.

The rock is described in the Survey Memoir as "fossiliferous, black and pisolitic, the concretions being about the size of small grains of barley."

It is a very tough rock, and in hand specimens from the above-mentioned locality the black grains, which are mostly ellipsoidal in shape, are from 1 mm. to 3 mm. in their longest diameter, and are somewhat sparsely scattered in a crystalline matrix, that is to say, they are not so crowded together as in the case of an ordinary piece of oolite limestone. The centres of the grains often show the bright cleavage face of a calcite crystal.

An analysis of the rock reveals the interesting fact that the black-

[1] Ramsay, Geology of North Wales, Mem. Geol. Survey, vol. iii.

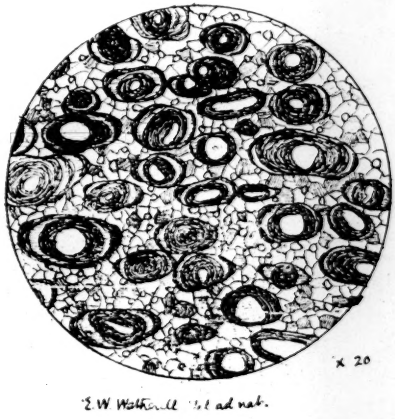


FIG. 1.—Section of Hirnant Limestone × 20.

The grains are made up of four layers—(1) Central nucleus of calcite. (2) Carbon. (3) "Chalcedonic" silica. (4) Outer bands of dusty material and carbon. (3) and (4) are sometimes repeated.

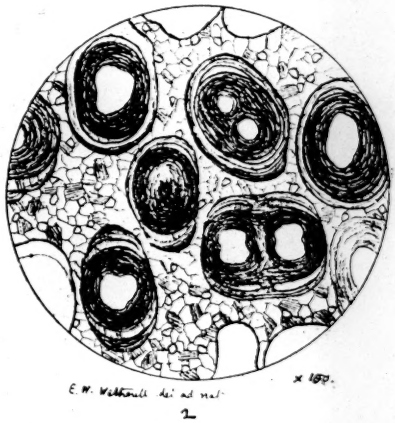


FIG. 2.—Section of Hirnant Limestone × 100.

To illustrate Mr. L. W. Fulcher's paper on the Composition and Structure of the Hirnant Limestone.

(p. 114.)

ness of the grains is due to *carbon* in an amorphous form. The following were the numbers obtained by a quantitative analysis:—

Insoluble residue (other than carbon)	18·35
Carbon	1·18
SiO_2 (soluble)	·27
FeO	1·57
CaO	42·85
MgO	1·05
CO_2	34·15
P_2O_5	1·35
H_2SO_4	·06
	100·83

These figures correspond to a total percentage of $CaCO_3$=72·82, $MgCO_3$=2·2, and $FeCO_3$=2·43. It also gives off a trace of SH_2 when dissolved in hydrochloric acid. The insoluble residue (including the carbon) contains approximately carbon 7 per cent.; SiO_2 77 per cent.; and $Fe_2O_3 + Al_2O_3$ 11 per cent.; the remaining 5 per cent. containing lime, etc.

The specific gravity of the rock varies slightly in different specimens from the same locality. Thus two determinations kindly communicated to me by Prof. Cole gave 2·604 and 2·67, while another for which I am indebted to Mr. Hume gave 2·642. These differences are readily explained by the variation in composition of this rock, even at distances of a few inches in the same specimen, which is shown when sections are observed under the microscope. Reference is made to this further on.

When a piece of the rock is treated with dilute hydrochloric acid, the calcite is gradually dissolved and the grains are left as little black hollow ellipsoids, together with a quantity of fine sand and carbon in powder. These black grains, when pressed by the finger on a piece of paper, soil both the paper and the fingers just like soot would do. But they are not wholly composed of carbon; for on heating them to redness in a platinum capsule, they turn of a reddish-brown colour, still retaining their shape, though all the carbon has been burnt off. It is easily seen now by applying the usual tests that these residues are composed of silica coloured by a little oxide of iron. Some of the black grains mounted in Canada balsam show a concentric structure, but this is much better studied in sections of the rock itself.

Amongst the residue of a piece of the rock about $1\frac{1}{2}$ inches square I also obtained some fragments of a very fine micaceous sandstone, the largest of which measured 11 × 8 mm. This particular fragment also had some very regular black markings on its surface, which I thought might possibly be leaf-scars; but on submitting the fragments to Mr. Boodle, this gentleman gave his opinion against this idea, but suggested that they might possibly be aggregations of fine sand around small vegetable filaments, as the carbon in the fragments seemed to occupy the hollows of very small canals. Of course this point cannot be settled until large quantities of the rock are dissolved, so that a good many of these fragments can be examined.

At present I have not the material for this purpose, but I have thought it well to mention the fact of the peculiar aspect of these sandstone fragments, as Ordovician plants are so rare that any indication of their existence is naturally a matter of interest. I may add that a section which I had prepared of the fragment did not reveal any noteworthy characters under the microscope.

When a section of the rock is examined under the microscope, we see the grains lying in a crystalline matrix of calcite (Pl. IV. Figs. 1–2, for the drawings of which I am indebted to the kindness of Mr. E. W. Wetherell). The centre of the grains consists usually of granular calcite, and in some cases has the form of a figure of 8, but is generally rather irregular in shape. Occasionally the nucleus is the fragment of an organism or a grain of sand. Around the centre the carbon appears as a series of opaque concentric rings, though now and then patches are seen to have been torn away in the preparation of the section. In a few cases the carbon seems to fill up the whole of the interior of the grain, but this is probably due to the fact that the centre of such grains has not been cut through. Externally the grains are seen to be increased in the direction of their longer axes by a secondary development of a fibrous-looking mineral. This statement, however, must be modified. In all the sections which I had prepared from my own specimens this secondary mineral appears; but Prof. Cole has lately lent me a slide in which it is entirely absent, so that the alteration is possibly only local. The fibrous-looking mineral from its optical properties seems to be a chalcedonic variety of silica. Under a high power the fibrous appearance is seen to be due to a number of thin elongated prisms which are apparently quartz. This mineral is itself bounded by a band of almost opaque material which sometimes includes carbon. There are often three or four bands of chalcedony separated from each other by a layer of the dusty material.

There is very rarely a radial grouping in the grains as in some Oolites, nor does there appear to be any such structure as the recently described *Girvanella*.[1] The grains give no black cross between crossed Nicols.

The matrix in which the grains are embedded is seen to be ordinary crystalline limestone, but it contains here and there fragments of organisms (Polyzoa), and also small irregular grains of quartz, which are by no means regularly dispersed, being in some places much more numerous than in others. These quartz grains often contain moving bubbles. It is also to be noticed that occasionally an extremely thin band of secondary calcite traverses the whole section, penetrating right through the grains. A section which has been mounted in Canada balsam, and then etched with hydrochloric acid so as to dissolve the calcite before being covered up, shows more clearly the concentric structure of the grains and the outer coating of chalcedonic silica which they possess.

It will be observed from the above description that the rock is somewhat analogous in structure to the Cleveland iron ore,[2] the

[1] Wethered, Geol. Mag. 1889, p. 196.

[2] Sorby, Q.J.G.S. vol. xxxv. (1879) Proc. p. 84.

Northampton iron ore,[1] and the pisolitic iron ore of Cader Idris.[2] It differs from all these, however, in the fact that the grains have a coating of carbon, and in the absence of the oxides of iron which form the chief constituent of the latter. It resembles all the above-mentioned rocks in the fact that the grains contain a skeleton of silica, and further in the presence of ferrous carbonate and phosphoric acid. It is most probable too that the silica skeleton in the case of the Hirnant limestone is due to the infilling of a cavity produced by solution of the calcium carbonate of the grains, which solvent action was prevented from extending inwards by the insoluble nature of the carbon. On the whole it seems that the rock owes its distinctive characteristics to vegetable agency,—the peculiar form of the carbon as well as the other chemical constituents lending evidence in support of this view. This evidence would be much strengthened if the sandstone residues described above should turn out to be a result of the existence of plant life as suggested.

IV.—On the Flexibility of Rocks; with Special Reference to the Flexible Limestone of Durham.

By George W. Card, A.R.S.M.;
Assistant Demonstrator of Geology at the Royal College of Science, London.

THE existence of rocks possessing, when the laminæ are not too thick, the property of flexibility has long been known. Upon flexible sandstone ("Itacolumite") a great deal has been written at different times, and of late years important work has been done which renders it necessary to greatly modify the opinions formerly held with regard to this rock. Notwithstanding the interest which is attached to the subject, it is one very much neglected by our text-books, the British, either ignoring it altogether, or treating it with the utmost brevity, the German, while sometimes referring to it at considerable length, do not do more than enunciate the old views. To Prof. Judd—who has kindly aided me with advice, and by affording facilities for preparing this paper—I owe the suggestion that it would therefore be useful to give a résumé of the present state of our knowledge upon the flexibility of rocks in general. This paper will accordingly be divided as follows:—

1. An account of the Durham Limestone.
2. Some remarks upon Flexible Sandstone.
3. A comparison of the two rocks.

1. *The Flexible Limestone of Durham.*—My attention was first directed to the existence of this rock by Mr. H. B. Woodward's "Geology of England and Wales."[3] Being well acquainted with the Sunderland district, I determined to take the first opportunity of looking for the rock, and, such an opportunity having occurred during the past summer, I now give the results of my work. So far as I am aware, there are only three references to this variety.

[1] Judd, Memoirs of Geol. Survey, Geology of Rutland, pp. 117–138; Hudleston, Proc. Geol. Assoc. vol. xi. p. 104.
[2] Cole and Jennings, Q.J.G.S. vol. xlv. (1889) p. 426.
[3] p. 219.

In his great memoir on the Magnesian Limestone, Prof. Sedgwick has the following passage:[1]—"The very thin laminæ of the latter (*i.e.* the earthy, finely-bedded limestone) variety, which occur in abundance near Marsden Rocks, are often slightly flexible, and very fine specimens of flexible magnesian limestone with thicker laminæ occur in a bed near the middle of the cliff." The second reference is that mentioned above, in "The Geology of England and Wales," and is to the same effect; while the third occurs in Bauerman's Mineralogy[2] under the heading "Dolomite," where it is stated that the stone is flexible when freshly quarried, implying that the property is transient.[3]

It would thus seem as if the Marsden locality were the only one from which flexible limestone has been described, but I was fortunate enough to procure beautiful specimens on the coast a little south of Sunderland, and therefore several miles from Marsden, which lies about two miles south of the mouth of the Tyne. For some distance south of the Hendon dock the cliffs consist of Glacial Drift; passing this, and following the cliffs, now composed of Magnesian Limestone, shortly before coming to the first point a position is reached where considerable falls of stone occasionally occur. It was from a recent fall that the specimens to be described were procured; the spot being about 1000 yards south of the Blue House Inn. From a similar fall in Marsden Bay, on the south side near the Rocks, I also obtained specimens, but these were inferior to those from Sunderland, and will not be again referred to.

The cliffs here are mainly composed of a laminated magnesian limestone; that from above being earthy, friable, and comparatively unaltered, while in the lower portion of the cliff the stone, while still tending to split along the bedding-planes, which are very clearly marked, has been compacted by the re-crystallization of the whole. It is from the upper part that the flexible variety comes. Owing to the strike corresponding approximately with the trend of the coast, the outcrop in the cliff is horizontal. Bedding is very perfect, and many perfectly level slabs, of several square feet in area, have been brought down by the fall. It was from these slabs that my specimens were procured; and I see no reason why, with care, very large specimens showing flexibility might not be obtained. The colour of the stone is light yellow, the surfaces of the laminæ are coated with a yellow powder which soils the fingers, lamination is sometimes very perfect (·75 mm.), the whole being uniformly very fine in grain, and requiring careful handling because of its softness and friability. In general appearance it is, indeed, not unlike a fine-grained sandstone, and appears to have resulted chemically from deposition in successive layers.[4]

An interesting feature is the occurrence of many minute nests of

[1] Trans. Geol. Soc. ser. ii. vol. iii. 1835, p. 87.

[2] Text-book of Descriptive Mineralogy, H. Bauerman, p. 353.

[3] However it may be at Marsden, this is certainly not the case at Sunderland. After having been kept in a dry place for several months, the specimens from the latter locality have undergone no loss of flexibility whatever.

[4] Sedgwick, *op. cit.* p. 86.

calcite; mostly of about three or four millimetres diameter. These appear of a brown colour when very small, but when larger this appearance is seen to be due to a coating of ferruginous matter which lines the cavity in which the crystals occur. In one case a perfect geode of about 1 c.m. in diameter and lined first with a ferruginous coating and then with calcite crystals occurred. The position of such a nest would be indicated externally only by a slight elevation on the surfaces of the lamina. This was especially the case with the geode mentioned above; its position was clearly indicated by a slight bulging of either side of the lamina in which it occurred, the protuberance being flattened and marked with concentric rings. It would seem as if such a geode might mark an incipient stage in the formation of some of the concretionary structures of which this series affords so many beautiful examples. A specimen in my own collection may well have originated in this way; it is flattened on one side, irregularly dome-shaped on the other, with a cavity open on the flat side, and extending into the interior of the dome. There are no cracks or any other communication across the planes of bedding, and the nests occur quite isolated—not in strings. It is therefore evident that they have originated in the bed itself.[1] These structures will again be referred to when the case of the flexibility is dealt with.

An analysis made under the superintendence of my friend Mr. W. Tate, A.R.C.S., gave the following results:—

CO_2	46·476
CaO	30·744
MgO	21·169
FeO	·518
SiO_2	1·028
Total	99·935

Notwithstanding the friability of the stone, sections can readily be prepared transverse to the bedding planes. Mr. F. Chapman, who prepared mine, tells me he had no difficulty after soaking the specimens in Canada-basalm. A low magnifying power reveals a large number of irregularly-shaped empty spaces, in the main arranged linearly in directions parallel to the bedding, but also occurring promiscuously through the section.[2] With a $\frac{1}{4}$-inch objective the section is resolved into an aggregate of grains of feebly-polarizing dolomite, the larger grains averaging about ·01 mm. in diameter, with a very few minute grains of quartz, and here and there of blue- and of brown-coloured minerals. With a $\frac{1}{4}$-inch, and still better with an $\frac{1}{8}$-inch, the grains are seen to be irregular in outline; the larger grains (sometimes attaining a diameter of ·02 mm.) frequently appear to be intergrown in such a way that a convexity of one fits into a convexity of another, or a projection into a depression. Very rarely a minute piece of mica occurs.

Having described the general appearance of the stone, the nature of its flexibility remains to be dealt with. In every case I find

[1] Sedgwick, *op. cit.*

[2] See Woodcut, Fig. A., p. 123, *infra*.

that the flexibility diminishes with the thickness of the lamina; pieces of 5 mm. or more in thickness exhibit the peculiarity in only a slight degree, while the laminæ of 1 mm. or less are very flexible indeed. Here, however, I may mention that the behaviour of specimens obtained from the same slab varied very much. A specimen of average flexibility and of 1 mm. or less in thickness feels almost leathery, bending over in all directions when held by one side or supported in the middle. A strip—trimmed down with a knife—5·3 cm. long, 2·5 cm. wide, and 1·5 mm. thick, supported at one end so that 5·3 cm. projected, gave the following results. By its own weight (4·4 grains) the strip bent until the free end was 1·6 cm. lower than the point of support. Now suspending it vertically it straightened itself in a few seconds and, on being turned over and once more supported at the same end, bent as before, but to not quite the same amount. By pressing the free end with the finger it was brought 3·1 cm. below the horizontal, when the strip broke off close to the point of support. Experimenting with another piece; after a little pressure had been applied to the free end, it straightened when suspended, but, when once more supported at one end in the same position, it assumed by its own weight a position approximating to that which it had been before bent by pressure.

With regard to the cause of flexibility I can only offer the following suggestions. In the first place, room for internal movement is provided for by the abundance of empty spaces, and in the second, the structure revealed by high magnifying powers suggests the possibility that many of the grains are interlocked in such a way as to permit of a certain amount of movement upon one another.[1] Such an explanation would not be incompatible with the coherency of the rock; as a matter of fact the coherency is very slight, the material crumbling to pieces with great readiness: moreover, many of the grains are to be bound together in such a way that their margins cannot be made out. Owing to the small size of the grains, it is impossible to demonstrate whether they have such power of movement or not.

The empty spaces have, no doubt, resulted from the removal of carbonate of lime by percolating water. The bedding-planes have afforded the easiest passage, and it is along these planes that the cavities for the most part occur. It would appear as if much of the material so dissolved had been redeposited as calcite in the geodes.

2. *The Cause of Flexibility in "Itacolumite."*—Before considering this question, it is very necessary to arrive at some sort of an understanding as to what the rock which has been known as "Itacolumite," "Flexible-Sandstone," "Flexible-Quartz," and a variety of other names,[2] really is. Towards the close of the last century a peculiar siliceous rock was noticed in Brazil. Attention was directed to it principally because it often constituted the matrix in which diamonds occurred, but also because thin pieces of it were sometimes found to be flexible. Owing to its occurrence in the mountains of Itacolumi,

[1] See Woodcut, Fig. B., p. 123, *infra*.

[2] Third Report on the Geognostic Survey of South Carolina, 1848, p. 85, et. seq.

early writers referred to it as "Itacolumite"; a list of such references will be found in Zirkel's "Lehrbuch der Petrographie" (Bd. ii. p. 484).

Subsequently similar rocks, also occasionally exhibiting flexibility, were discovered in other parts of the world, more especially in the Southern States of North America, and, at a later date, in India.

The term "Itacolumite" has been applied to the rock itself by most writers; Tuomey, who restricts it to the flexible variety, is an exception. The accounts given of the rock are fairly consistent, all agreeing in describing it as a stratified and granular variety of quartzite; frequently, especially in the case of the Brazilian and Carolina specimens, a good deal of mica occurs upon the bedding-planes.

Coming now to the terms applied to the flexible portion, "Sandstone" may be objected to on the ground that flexibility is at present unknown in unaltered siliceous sedimentary rocks, but Prof. Derby has pointed out[1] that there is no reason why it should not occur in sandstone.

Almost without exception the flexibility sometimes exhibited by "Itacolumite" has been ascribed to the quartz grains being enveloped by a flexible mineral variously referred to as mica, sericite, talc, or chlorite. As exceptions I may mention Klaproth and Prof. Haughton, both quoted[2] by Mr. Oldham, and von Hausmann, referred to by Zirkel.[3] Leibner, in the report on South Carolina before quoted, devotes a good deal of attention to the cause of flexibility, and considers that four conditions must be fulfilled, viz.:

1. "Fineness of grain."
2. "Sufficient admixture of mica or talc."
3. "Delicately laminated structure."
4. "Certain degree of compactness in the constituents of each lamina."

In this way he explains the very local occurrence of portions, since all the conditions must be fulfilled simultaneously. It would seem as if the flexible-mineral theory was at first nothing but a suggestion, but Leibner definitely gives his assent to it. Leaving the older views—which are still given in most text-books—two important papers have been lately published by Mr. Oldham,[4] and by Prof. O. Mügge respectively,[5] which propound quite different views as to the cause of flexibility. To these may be added a third by Prof. Derby[6] on the mode of occurrence of the Brazilian specimens. Prof. Derby's paper deals with the very local occurrence of flexible portions in the Itacolumite Series; the same mass of rock may contain "massive and schistose, compact and friable, non-flexible

[1] Am. Journ. Sci. xxviii. 1884, p. 205.
[2] Rec. Geol. Surv. India, vol. xxii. pt. 1, 1889, p. 53.
[3] Lehrbuch der Petrographie, 1886, Bd. 11, p. 482.
[4] On Flexible Sandstone or Itacolumite, R. D. Oldham, A.R.S.M., Records Geol. Surv. India, vol. xxii. pr. 1, 1889.
[5] Ueber "Gelenksandstein" aus der Umgegend von Delhi O. Mügge, Neuen Jahrbuch, Bd. i. 1887.
[6] On the Flexibility of Itacolumite, Orville A. Derby, Am. Journ. Sci. vol. xxviii. 1884.

and flexible portions, within a distance of a few centimetres, and in exactly the same relative position in the bed." The author's conclusion is that flexibility is a *phase of weathering*. Tuomey came to the same conclusion with regard to the South Carolina stone, but Leibner differed from him.

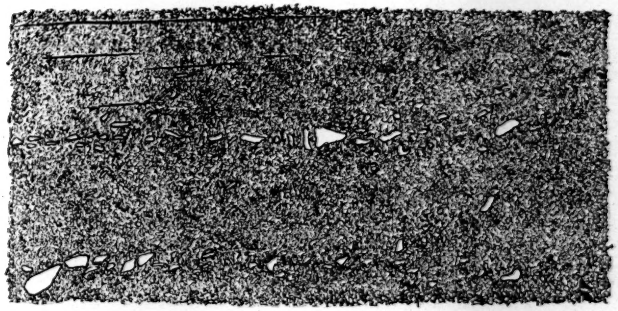
Mügge describes the Delhi stone. There is a very little muscovite, but so small a quantity that it cannot possibly give rise to the flexibility. A small amount of clayey matter is present, not surrounding the quartz grains, but in patches which are not sufficient to fill the interspaces; the quartz is therefore much clearer than in ordinary sandstones, and the grains are in direct contact with one another; moreover, the grains have a very irregular outline (comparable to Babel-quartz), being very different in appearance from those of common sandstone. When examined in thin sections by means of polarized light, the quartz grains are seen to be hooked together. This interlocking accounts for the grains holding together, and at the same time allows of a certain amount of movement taking place, space for movement being afforded by the decomposition of the clayey patches. In this way the author thinks the flexibility can be explained. Dealing briefly with the Brazilian stone, he shows that the quartzes present an appearance almost identical with the Indian; there is very little clayey material, so that a section is almost as clear as water; while muscovite occurs only in small quantity, and in flakes much too short to envelop the quartz-grains. It is suggested that the structure of these rocks originated by a partial removal of the cementing material; the quartz-grains then resumed their growth, but the supply of material failed before the interspaces left on the removal of the clayey matter were completely filled.

Mr. Oldham, also dealing with the Delhi specimens, arrived independently at the same results. In India, as in Brazil and in South Carolina, flexibility is correlated with decomposition. Examined under the microscope by reflected light a number of quartz-aggregates, separated by vacant spaces which appear to be ramifying fissures, are seen. These aggregates can be moved by a needle without displacement, the movement being the result of the grains being hinged together, a projection from one fitting into a depression in another. He also notices the occasional presence of felspathic paste, which, by its relative abundance and mode of distribution, determines the degree of flexibility that will be possible on its decomposition and removal. Having regard to the subject of this paper, one of the specimens described by Mr. Oldham is of special interest. It is a variety from Chárli, south of the Pemganga River (Berar). "An ordinary soft sandstone of rounded grains of quartz, with a little felspar, held together by a cement of carbonate of lime, *which forms 35·9 per cent. of the whole mass.*[1] Here there is no comparatively soluble material whose removal leaves the rest of the rock as a mass of irregular aggregates interlocking with each other, for on removal of the cement, by solution, the rock falls into sand.

[1] The italics are mine.

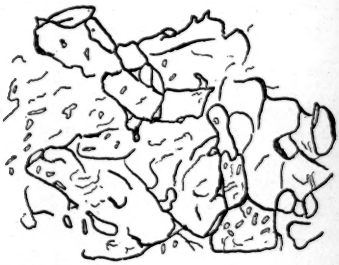
But if the fractured surface of the rock is examined, an abundance of sheeny patches point to a crystallization of the cementing matrix, and these crystals offer a number of planes in various directions along which solution proceeds with greater rapidity than elsewhere; and as a result the rock becomes divided into irregular interlocking aggregates of sand and calcite."[1] The mode of interlocking in both varieties is illustrated by drawings.

Section of Flexible Limestone from the coast, a little south of Sunderland (see *ante*, pp 118–120).



Del. Geo. W. Card.

FIG. A.—Flexible Limestone cut transverse to bedding, and showing empty spaces. × 10. (p. 119.)



Del. Geo. W. Card.

FIG. B.—Flexible Limestone highly magnified. × about 400. (p. 120.)

An examination of a section of the North Carolina material in the collection of this institution gives similar results: the quartzes are very clear, have very irregular outlines, and are generally in direct contact; there are a number of cavities, and apparently an articulation of the grains, while mica is present in very small quantity only.

3. It will now be useful to briefly compare these "sandstones" with the Durham Limestones. In thin laminæ the flexibility is very similar in degree; Leibner found that a strip of Carolina Sandstone, very similar in dimensions to the strip of limestone used by myself,

[1] p. 54.

but a little thicker ($\frac{1}{10}$-inch), bent under pressure through a vertical distance equal to somewhat less than half the length of the strip; the limestone gave slightly higher results, but was somewhat thinner (1·5 mm.). In slabs of greater thickness, however, the superior flexibility of the Itacolumite is very marked; thus Mr. Oldham found a piece 17 inches long by ·75 inch thick bent through 7 inches of its own weight, while in slabs of limestone of 5 mm. thickness flexibility becomes very slight. They agree also in a decrease of flexibility accompanying increase of thickness. In both cases the occurrence of flexible portions is very local; this has already been referred to, but it may be mentioned further that fine-grained, bedded, non-flexible limestones occur in the neighbourhood, and it would be interesting to know whether these non-flexible beds possess the internal structure described above. It is, however, in internal structure that the resemblance is most marked, both exhibiting a number of vacant spaces accompanied by an interlocking of the constituent crystalline grains. Flexibility would thus seem to arise from similar causes; we have room for movement afforded by empty spaces, the result of solution of carbonates in the one, and of the decomposition and removal of patches of felspar in the other; while the direct cause of bending is the interlocking of the grains.

It is well known that a distinct sound is heard when flexible sandstone is bent; the limestone does not give rise to any sound that is audible, but, from the inferior hardness of calcite, as compared with quartz, this is no more than might be expected.

Lastly, there is the occurrence of the calcareous rock at Chárli. This may, indeed, be regarded as a connecting link between flexible Itacolumite on the one hand and flexible limestone on the other. It is not only that it contains a certain proportion of carbonate of lime; that might be quite a matter of detail; but from the passage quoted above it would seem that the calcite plays an important part, forming interlocking aggregates, and affording the space necessary for movement by its solution. Moreover it is described as a common sandstone, the grains of quartz being somewhat rounded; this would seem to emphasize the presence of the calcite, as it is not clear what part such quartz can take in effecting movement.

In conclusion, now that a number of rocks are known to exhibit the property of bending without fracture, in each case the phenomenon being no more than a natural concomitant of certain phases of alteration, the undesirability of giving distinctive names to the different varieties will be at once apparent. Indeed, there seems no reason why many other varieties should not also occur, although, from the nature of the conditions to be fulfilled, we cannot expect to find flexible beds in considerable quantity.

I have already acknowledged my indebtedness to Prof. Judd, and it only remains to state that this work has been carried out in the Geological Laboratory of the Royal College of Science.

REVIEWS.

I.—Classification of the Moas (Dinornithidæ) of New Zealand.

We have received from Prof. F. W. Hutton, F.G.S., an abstract of a paper read by him at the Canterbury Philosophical Institute on Oct. 1st, 1891, in which the classification of the extinct flightless birds of New Zealand is discussed. Mr. Lydekker having recently treated the subject at length in the British Museum Catalogue of Fossil Birds, from an examination of the material now in the Museums of London, Capt. Hutton's work is especially opportune; and it is to be hoped that before the printing of this memoir, based upon the unrivalled specimens in the New Zealand Museums, the author will have the opportunity of incorporating the results of his British co-labourer. Both Mr. Lydekker and Capt. Hutton recognize several new specific types, and it is especially desirable that the forms just determined by Mr. Lydekker should not be re-named in the forthcoming work.

Captain Hutton regards the known Dinornithidæ as divisible into seven genera and twenty-six species. "The genera are founded chiefly on the skulls, but also have characters derived from the sternum, pelvis, and the robustness of the leg-bones. The species are distinguished almost entirely by size, but sometimes characters derived from the skull can be given. In many cases the species run one into the other, and the lines between them are drawn so as to give about an equal range in variation to each species."

The generic diagnoses are as follows:—

Genus Dinornis. Skull depressed, the lambdoidal ridge flattened and the parietals hardly rising above it; the breadth at the squamosals greater than the length from the supra-occipital to the nasals. Beak rather longer than the head, depressed and obtuse at the tip; the lower jaw much curved. A scapulo-coracoid without any glenoid cavity. Including sub-genus *Dinornis* ("Top of head flattened") with species *altus*, *maximus*, *giganteus*, *robustus*, *ingens*, and four new species; also sub-genus *Tylopteryx* ("Top of head elevated") with species *gracilis*, *struthioides*, and one new form.

Genus Palapteryx. Skull depressed; the breadth of the squamosals less than the length from the supra-occipital to the nasals. Beak about as long as the head, more compressed than in *Dinornis*; the lower jaw nearly straight. A scapulo-coracoid with a glenoid cavity and probably a wing. Including *P. dromioides* and one new species.

Genus Anomalopteryx. Skull very convex, the maxillo-jugals curved. Beak short, slightly compressed and rounded at the top; the lower jaw strong and nearly straight. A small scapulo-coracoid. Including *A. didiformis* (=*A. parvus*), and one new species.

Genus Cela. Skull convex. Beak short, slightly compressed and rounded at the tip; the lower jaw nearly straight and rather slighter than in *Anomalopteryx*. No scapulo-coracoid. Including *C. geranoides* and *C. curtus* (=*Dinornis Oweni*, Haast).

Genus Mesopteryx. Skull convex, angled behind. Beak shorter than the head, moderately curved, much compressed and pointed at the tip; the lower jaw slender. No scapulo-coracoid. Including *M. didinus* (=*Dinornis Huttoni*).

Genus Syornis. Skull convex, rounded behind. Beak shorter than the head, moderately curved, much compressed and pointed at the tip; lower jaw strong. No scapulo-coracoid. Including *S. rheides*, *crassus*, and *casuarinus*.

Genus Euryapteryx. Skull moderately convex. Beak very short and stout, slightly compressed and rounded at the tip; the lower jaw moderately curved. No scapulo-coracoid. Including *E. elephantopus* and *E. gravis*, with two new species.

In a popular summary of his results, contributed to a local newspaper, Captain Hutton makes some interesting comments on the remarkable diversity thus recognized among the extinct Struthious birds of New Zealand. He considers that a plausible explanation of the facts may be deduced from the known distribution of the existing Cassowary. One species inhabits Australia at the present day, and eight others occur on the islands from New Britain to Ceram. The eight species inhabit five different islands, "and if this region of the earth were to be elevated, and the islands joined together, these eight species would mingle. If the region were to sink once more all of them would be driven to the highest land, and might be crowded into one small island. Now, we know from geology, that New Zealand has gone through a series of changes in level, similar to those just mentioned. In the Miocene period it consisted of a cluster of several islands, which were elevated and united in the older Pliocene, and ultimately divided into the two islands we have now in the newer Pliocene. If the ancestors of the Moas inhabited New Zealand during the Eocene period, they must have been separated on these islands during the whole of the Miocene, and mingled together again in the Pliocene. In this way—*i.e.* by isolation—probably the genera originated, but the species appear to be due to variations without isolation. As is the case with most common animals, the Moas varied greatly, and, there being no carnivorous mammals to hold them in check, while vegetable food was abundant, natural selection did not come into play, and the intermediate forms were not strictly eliminated. Under such favourable circumstances the conditions of life were easy, and the birds got larger and fatter, more sluggish and more stupid. The oldest known Moa is one of the smallest, and it is the smaller species which are found in both islands; from which we may infer that they were the only ones in existence when the two islands were united, and that the Moas since then increased in size. But the very large Moas were always comparatively rare. The commonest kinds in the North Island were only from two and a half to four feet high, while those of the South Island were mostly from four to six feet in height. The giant forms, going up twelve and thirteen feet, were seldom seen."

Such speculations are an incentive to further research, and both zoologists and geologists will anxiously await the appearance of a memoir that will evidently touch problems of very wide import.

II.—Mémoire sur la Faune du Grès Armoricain, par Charles Barrois. Annales de la Société Géologique du Nord, Tome xix. pp. 134–237, Pls. I.–V. April, 1891.

THE rocks in Brittany known as the 'grès armoricain,' have a special interest from the fact that they are pretty well the lowest in France from which specifically determinable fossils have been obtained. M. Lebesconte has partly described and figured from them, fragments of Trilobites belonging to the genera *Ogygia* and *Homalonotus* and some years since the late Dr. T. Davidson[1]

[1] Geol. Mag. Vol. VII. (1880), p. 342, Pl. X.

figured and described in the pages of the GEOLOGICAL MAGAZINE several species of *Lingula* from the same horizon. A few other fossils, Mollusca principally, were also known in these beds; but owing to the fact that these forms were in poor preservation, existing only as moulds, no systematic attempt had been made to determine them. In spite of this obstacle Dr. Barrois has succeeded in working out this group, and has described and figured in this memoir no fewer that 29 species of Lamellibranchs, 13 of which are new forms. The principal genera represented are *Actinodonta*, Phillips; *Lyrodesma*, Conrad; *Redonia*, Rouault; *Ctenodonta*, Salter; *Nuculites*, Conrad; *Nuculana*, Link; *Cyrtodonta*, Billings; *Modiolopsis*, Hall, and *Hippomya*, Salter. The Gasteropoda are included in *Palæacmœa*, Hall, and *Bucania*, Hall, and there is a single species of *Conularia*. There are also some Crustacea referred to *Myocaris*, Salter; *Ceratiocaris*, M'Coy, and *Trigonocarys*, gen. nov. Specimens of the peculiar fossil *Discophyllum* (*Actinophyllum*) *plicatum*, Phillips, sp., also occur in the grès armoricain, and they are ranked by the author as calcareous sponges, similar to those of the family Pharetrones, Zittel; but after a careful examination of Phillips' types, we fail to recognize any characters which can ally them to sponges.

Including forms previously known, Dr. Barrois now enumerates a list of 45 species of invertebrate fossils from the 'grès armoricain' in the departments of Ille-et-Vilaine and Loire Inférieure.

Taking into account the occurrence of the genera *Ogygia* and *Homalonotus*, and of the Lamellibranchiata now described, the author is fully justified in concluding that the fauna cannot be Primordial, but he considers that it is intermediate between this latter and the Llandeilo fauna. There is a very significant similarity between many of the Lamellibranch genera of the 'grès armoricain' and those occurring in the Trenton and Chazy groups of Canada and the United States, thus indicating a nearer relation to these rocks than to the underlying Calciferous formation in these countries. Again, when compared with British strata, the molluscan fauna of the 'grès armoricain,' approaches nearer to that of the base of the Arenig than to that of the older Tremadoc. If this supposition is correct, the fauna of the 'grès armoricain' cannot correspond with the earliest period of the second Silurian fauna, and consequently neither a Tremadoc nor a Primordial fauna has yet been discovered in Brittany. Notwithstanding the identity of the Bilobites and Scolites in the 'grès armoricain' with those of the Lingula Flags, the author states that these rocks cannot be compared together in point of age.

Touching the classification of the schists, conglomerates, phyllades, etc., which in Brittany occur beneath the 'grès armoricain,' considerable differences of opinion exist among French geologists, but Dr. Barrois adopts that of Dufrenoy, and considers the Étage of Gourin to correspond with the horizon of the Primordial fauna, and the phyllades of St. Ló with the Longmyndian of Callaway.

G. J. H.

III.—Om mynningen hos *Lituites*, Breyn. Af Gerhard Holm. Geol. Fören. Forhandl. No. 140, Bd. 13, Häft 7, 1891.

On the Aperture in the genus *Lituites*, Breyn. By Gerhard Holm. Transactions of the Geological Society in Stockholm, Vol. 13, pp. 736–780, Pls. 10–12.

THE terminal aperture of the shell in the Lower Silurian Cephalopod genus *Lituites*, Breyn, is so seldom preserved intact, that different views have been maintained respecting its true form. Quenstedt stated that it was furnished on the ventral side with two projecting straight lobes. Noetling showed later that there were four of these lobes, one pair on the ventral and the other on the dorsal side; but in the lately published Brit. Mus. Cat. of the Cephalopoda, A. H. Foord adopts the statements and figures of Lossen that not more than two incurved lobes are present, and considers Noetling's observations erroneous. Dr. Holm has obtained some very perfect individuals both of *Lituites lituus*, Montf., and *L. tenuicaulis*, Rem., which show clearly that in the aperture of these species, there is, in addition to the two pairs of lobes described by Noetling, another small unpaired lobe on the dorsal side, so that, when complete, there are five lobes. This number seems to prevail in the majority of the species, but the author describes a new form, *L. discors*, in which only three lobes are present, and another, *L. præcurrens*, which may possibly only have possessed two lobes, and on account of its strongly marked conical form would come into the so-called genus *Ancistroceras*.

A new species of *Cyclolituites*, Remelé, is also described, which definitely shows that the forms placed in this genus are not merely the loose spirals of species of *Lituites*, but distinct members of the Lituitidæ family, from which probably the typical *Lituites* have been developed. G. J. H.

IV.—The Fossil Insects of North America, with Notes on some European Species. By Samuel H. Scudder. Vol. I. The Pretertiary Insects, with Thirty-five Plates. 4to. pp. 456. Vol. II. The Tertiary Insects of North America. 4to. pp. 734, with Twenty-eight Plates.[1] New York: Macmillan & Co. (1891).

THE Essays contained in the first volume of the present work have (the author tells us) no logical connection. They were written and printed at different times during the past twenty-five years, and are here issued exactly as first printed. But they cover nearly the whole of a single limited field in palæontology, of which the author may be said to be almost the sole exponent in America. Mr. Scudder's name is now as familiar to European Palæontologists as it is to those of America, and, so long ago as 1868, he communicated to the Geological Magazine, at the request of Sir Charles Lyell, a most valuable digest "On the Fossil Insects of North America," so far as then known (Geol. Mag. Vol. V. pp. 172–177, and pp. 216–222).

[1] For a Review of vol. ii., see Geol. Mag. 1891, Decade III. Vol. VIII. pp. 280–282.

1. The volume opens with an essay on "the first discovered traces of Fossil Neuropterous Insects in North America," and was read before the Boston Society of Natural History, in January, 1865, (published in 1866 with one plate).

2. The second is on "the Carboniferous Myriapods preserved in the Sigillarian stumps of Nova Scotia."

3. Next follows a short essay on "the early types of Insects; or the origin and sequence of Insect-life in Palæozoic Times."

4. The fourth paper on "Palæozoic Cockroaches," *with a revision of the species of both worlds*, and an essay on their classification (illustrated by five quarto plates), is one of Mr. Scudder's most important contributions.

At first glance at the plates it would appear as if the materials at the author's disposal were better preserved and more abundant than usually falls to the lot of any single student of fossil insects; but the figures occupying the first three plates out of the five illustrating this paper, are copies from the plates of Germar, Goldenberg, Giebel, Heer, etc., of all the then known European forms (1879), the last two only being drawn from original American specimens.[1]

It is doubtless a very great convenience to have the whole of the forty-nine European forms redrawn and brought together thus for comparison with the eighteen American species, but the complete *revision* of all the European species, from the figures and descriptions alone, must be a somewhat hazardous task without seeing the original specimens as well. However, we may be very thankful to Mr. Scudder for his scheme of classification, nor are we likely to better it, for some time to come.

The specimens figured are all detached wings, and the proposed arrangement is based solely upon their neuration.

5. The next Memoir is on "The Devonian Insects of New Brunswick" (illustrated by Plate 7), first described and figured (by Scudder) in a paper by Sir William Dawson in the Geol. Mag. 1867 (Vol. IV. pp. 385–388, Pl. XVII. Figs. 1–5).

6. The sixth Memoir is on the "Archipolypoda, a subordinal type of spined Myriapods from the Carboniferous formation" (with four plates).[2] This Essay is particularly interesting to English palæontologists on account of the discovery of similar forms of spined Myriapods in the English Coal-measures.[3]

7. The next paper is on "The Carboniferous Hexapod Insects of Great Britain," and describes and figures (*a*) *Brodia priscotincta*, Scudder, from a Clay Ironstone nodule of the Coal-measures, Tipton, Staffordshire; (originally described and figured (as a woodcut) in Geol. Mag. Dec. II. Vol. VIII. p. 293, 1881). (*b*) *Archæoptilus ingens*, Scudder, a fragment of the base of the wing of a large Neuropterous insect, from the Coal-measures near Chesterfield, Derbyshire, and

[1] Mem. Soc. Nat. Hist. Boston, 4to. vol. iii. pp. 23–134, pls. 2–6.

[2] Originally published Mem. Boston Soc. Nat. Hist. vol. iii. No. v. pp. 143–182, pls. x–xiii. 1882.

[3] See H. Woodward, "On some Spined Myriapods from the Carboniferous Series of England," Geol. Mag. Dec. III. Vol. IV. Pl. I. pp. 1–10, 1887.

is like the preceding example in the collection of the Rev. P. B. Brodie (GEOL. MAG. 1881, p. 295).

8. This paper is on "Two New and Diverse Types of Carboniferous Myriapods;"[1] namely *Trichiulus villosus*, *T. nodulosus*, and *T. ammonitiformis* (no longer a myriapod). *Palæocampa anthraz* from the ironstone nodules of Mazon Creek, Morris county, Illinois (illustrated by two plates).

9. The ninth paper is on "the species of *Mylacris*, a Carboniferous genus of Cockroaches," of which Mr. Scudder describes six species founded on six detached wings, which are also figured. They are from Mazon Creek, Pittston, and Cannelton, Pennsylvania.

10. This essay is devoted to "The Earliest Winged Insects of America: a re-examination of the Devonian Insects of New Brunswick, in the light of criticisms and of new studies of other Palæozoic types."

Surely these remains are too fragmentary and obscure to devote more time to their re-examination or lengthy discussion. It would be more profitable to look for better materials to study.

11. On "Palæodictyoptera: or the affinities and classification of Palæozoic Hexapoda."

In this paper the author describes and figures (in four quarto plates) a number of new Carboniferous winged insects principally from Mazon Creek, Illinois. One form, *Archægogryllus priscus*, is considered to belong to the Orthopteroid-Palæodictyoptera; but the twenty-three other forms named and figured are referred to the Neuropteroid section. The neuration of many of these forms, preserved in ironstone nodules, is obscure and very difficult indeed to trace with accuracy, and therefore their determination must be to a considerable extent tentative.

12. "Winged Insects from a Palæontological point of view, or the Geological History of Insects." In this paper the author contends that throughout Palæozoic times insects continued as a generalized form of Heterometabola which he calls Palæodictyoptera, and which had the front wings, as well as the hind wings, membranous. On the advent of Mesozoic times a great differentiation took place, and before its middle, all of the orders, both of Heterometabola and Metabola, were fully developed in all their essential features as they exist to-day, the more highly-organized Metabola gradually becoming the prevailing type (p. 322).

13. The thirteenth paper is on "the oldest-known Insect-larva (*Mormolucoides articulatus*) from the Connecticut River Rocks" (Triassic).[2] (See pl. 19, and woodcut, p. 323.)

14. This is "A Review of Mesozoic Cockroaches," dealing with the Secondary forms of Blattariæ after the manner in which the Palæozoic forms were dealt with in Essay No. 4, only in this case *all the species* figured and described are British or European, but almost all are from the Lias or the Purbecks of England. Many of

[1] Originally printed in Memoirs of the Boston Society of Natural History, vol. iii. No. ix. 1884.

[2] Published in the GEOL. MAG. Vol. V. 1868, p. 218, without a figure.

them are based on fragments from the Purbeck, which Westwood named but did not describe; or figured, but did not name; or, which Brodie found but did not name or describe. These wings are for the most part fragmentary and must have required good courage to found species upon them. Surely there is something wrong about *Pterinoblattina penna!* (pl. 22, fig. 14). Is it an insect-wing at all?

15. Is on some "New Types of Cockroaches from the Carboniferous Deposits of the United States." These forms, which fill two quarto plates, are considerably better-preserved remains than any of the others previously figured; fig. 5, pl. 23, *Archimylacris paucinervis*, and fig. 3, pl. 24, *Oryctoblattina occidua*, being very remarkable and aberrant forms. These cockroaches are from the Richmond, Ohio, coal-field, and from Mazon Creek, Illinois.

16. This paper is devoted to more "New Carboniferous Myriapoda from Illinois." The greater number of specimens are referred to the genus *Euphoberia* and to eight species. The other to *Acantherpestes*, *Archiulus*, *Xylobius*, *Ilyodes*, *Latzelia*, *Palænarthrus* and *Eilecticus*. These are mostly from Mazon Creek, Illinois, and are very beautifully drawn on six quarto plates illustrated by fifty-seven figures.

17. Is devoted to "Illustrations of the Carboniferous Arachnida of North America of the orders Anthracomarti and Pedipalpi."

The Anthracomarti is said to be the only extinct order of Arachnida, and was established by Karsch for some interesting Carboniferous forms allied to the Phrynidæ and Phalangidæ, although very distinct from either of them.

To this group belong forms like *Eophrynus Prestvici*, H. W. (1871), from the Coal-measures, Coalbrook-dale; *Architarbus subovalis*, H. W. (1872), Coal-measures, Lancashire; numerous allied forms from the Permo-Carboniferous of Bohemia. Another form, named by Woodward as *Brachypyge carbonis* (Geol. Mag. 1878, Pl. XI. p. 434), from the Coal-measures of Belgium, has since been removed (at the suggestion of Mr. Scudder) to the Anthracomarti, near to *Eophrynus* (see Geol. Mag. 1887, p. 49, footnote). Scudder's genus *Geraphrynus* (pl. 32, figs. 1, 9, 10) and his *Anthracomartus* (pl. 31, figs. 7–10) must be very near to *Eophrynus*. Of the order Pedipalpi, Scudder's *Geralinura carbonaria* is also represented in the Coal of Bohemia by several closely allied species.

18. The last paper is on "The Insects of the Triassic beds at Fairplay, Colorado." These include thirteen species of Palæoblattariæ and Blattariæ and three species of Hemiptera. The descriptions of these cockroaches are based on wings, but two or three species are founded on the pronotum alone.

The volume concludes with a Biographical note on American Literature, treating of the older fossil Insects; followed by an Index and thirty-four excellent plates.

Most of the papers are undated and need references, but they have, as a rule, been all published, in their present form, at various times, in the Memoirs of the Boston Society of Natural History.

Vol. II., which treats of the Tertiary Insects of North America, is a reprint from vol. xiii. of the Report of the United States Geological

Survey of the Territories (1890), which has already been noticed (see GEOL. MAG. 1891, p. 280). It includes the (Oligocene) Tertiary Insects of Florissant, South Colorado; those of the White River, West Colorado; Eastern Utah; and Wyoming.

From Quesnel, British Columbia, Dr. G. M. Dawson has contributed numerous insects; and Dr. G. J. Hinde from Clay-beds, near Toronto, Canada, has added materials for 29 species.

Alas! but few of those who, like the author, have devoted a life-time to palæontology, ever have the good fortune to see, at the end of thirty years, their scattered brochures reprinted as a pair of handsome quarto volumes! To many of us, the process would certainly not be feasible, *commercially*. To most it would hardly be a scientific gain. Compared with man's best efforts after all, how much more enduring is the Epitaph which Nature has engraved upon the rocks to the Memory of the humble but long-lived Cockroach!

* * * * * * *

Diving into our Editorial waste-paper basket to-day we drew forth the following lines, grimy with soot, and inscribed :—

"MANCHESTER, BRIT. ASSOC. 1887.

"In times Carboniferous Scudder has shown,
That the Cockroach was gaily then holding his own;
Do you think that in our case we too may last,
If we stick to the Cook and the Kitchen as fast?"

(The second verse has, alas! been torn off, and is lost to science.)

H. W.

V.—GEOLOGICAL SURVEY OF WESTERN AUSTRALIA. ANNUAL GENERAL REPORT FOR THE YEAR 1890. By HARRY PAGE WOODWARD, F.G.S., etc., Government Geologist. 8vo. pp. 53. (Perth, W.A., 1891.)

THE last Report of the Government Geologist in Western Australia, was noticed in the GEOLOGICAL MAGAZINE for October, 1890 (p. 468); and we then printed a Table of the Strata, which need not here be repeated, as no additions or alterations are necessary.

In the present Report Mr. Harry P. Woodward gives a list of the fossils which, up to the present time, have been found in Western Australia. Some of these have been described in the GEOLOGICAL MAGAZINE, as previously noticed.

Among the Cambrian fossils, the record of *Olenellus Forresti*, associated with *Salterella Hardmani*, is of especial interest. Although this *Olenellus* was identified with a query by Mr. A. H. Foord, yet further knowledge of the genus, as lately published by Mr. C. D. Walcott, leaves no room to doubt that the query may be cancelled; and indeed this element of doubt has been omitted from the Report. With regard to the Carboniferous and Devonian rocks it is remarked that "there seems to be an unbroken series of beds, the Lower Carboniferous fauna gradually merging into the Devonian"—a matter of considerable interest, as this is undoubtedly the case in Europe and North America.

In future lists of the fossils it would be convenient if the names of authors were appended; and the opportunity might be taken to correct some misprints in the names.

The Report contains a general geographical and geological description of the Victoria, Murchison, Gascoyne, Ashburton, Fortescue, Roebourne, and De Grey districts, with particular accounts of the mineral resources.

Alluvial gold was found by the Ashburton river in 1890; it has been derived from mineral veins in clay-slates. These slates are highly inclined, and on their upturned edges rest limestones and other strata of Devonian and Carboniferous ages. The Ashburton gold-field yielded about 15,000 ounces of gold in six months. At present only the rich patches in the shallow ground have been worked; the deep ground is as yet untouched, although in the large plains of the Ashburton river rich deposits are sure to be found, and it is likely to prove a permanent goldfield.

Mr. Woodward remarks that "as the prospecting will be most expensive work, no one will undertake it, unless he be granted a protection area, until the course of the leads has been ascertained."

The Pilbarra Goldfield is also reported to be "one of the most promising mineral areas in this Colony." Particulars are likewise given of the progress of the Yilgarn and Kimberley Goldfields, of the Greenbushes Tinfield, and of the Collie River Coal-district.

The Collie Coal is stated in the Report to be "a Mesozoic coal, of first class quality," but from specimens subsequently submitted to Mr. Etheridge, he expresses his belief that it is "a good and true Palæozoic coal" (*West Australian*, Jan. 13, 1892). The question of age will not seriously affect the colonists, so long as the coal is good, and there is plenty of it. The extent has yet to be proved.

VI.—Guide through the Collection of Building-materials in the Imperial-Royal Natural-History Court-Museum of Vienna. [Führer durch die Baumaterial-Sammlung, etc.] compiled by Felix Karrer; with a Preface by the Editor, Dr. Aristides Brezina, Director of the Mineralogical Department. Small 8vo. 302 pages, with 40 Illustrations. Vienna, 1892.

IN the Introduction the rocks and minerals supplying materials for construction are enumerated and briefly described, and then referred to their respective geological ages and formations. A bibliography relating to building-materials is also given.

The contents of this useful work are arranged thus:—I. Austrian-Hungarian Monarchy: A. Cisleithania; 1. Lower Austria, especially Vienna, with illustrations of St. Stephen's, the Votive Church, Government Buildings, Townhall, Natural-history Court-Museum, Marie-Therese Monument, the University, Court-Town-theatre, and the Court-Operahouse. The enumeration, definition, and localities of the several kinds of natural and artificial stone, plaster, etc., are carefully given, as road-materials, paving-stones, brick-earths, mortar-sand, lime, cement-stones, building-stones, decorative-stones,

roofing-slates, artificial stones, fire-bricks, terra-cotta, stucco, etc. A supplemental list of materials besides those used in Vienna; and one of the old collection of the Society of Austrian Engineers and Architects, are added. 2. Upper Austrian; 3. Salzburg; 4. The Tyrol; 5. The Vorarlberg; 6. Styria; 7. Carinthia; 8. Carniola; 9. Görz and Gradisca; 10. Trieste; 11. Istria; 12. Dalmatia; 13. Bohemia; 14. Moravia; 15. Silesia; 16. Galicia; 17. Bukowina. For these districts, the chief cities are noted with illustrations of several important buildings, and an enumeration of the local building-materials in relatively the same order as those described for Vienna.

B. In the Kingdom of Hungary, we have—(1) Budapest, its chief buildings and materials; also (2) the materials used in Siebürgen, and (3) Croatia.

II. The foreign localities and their building-materials here mentioned are:—Germany, Italy[1] (including ancient Rome), France, and Belgium, with illustrations of several of their chief buildings; also lists from England, Norway, Russia, Switzerland, Spain and Portugal, Greece, the United States of America, Asia, and North Africa.

The assistance given to the author by merchants, manufacturers, and scientific friends, with information and specimens, is duly acknowledged throughout the book.

This catalogue raisonné of Eastern-European and other building-materials is a very valuable addition to the bibliography of the subject; and the fine collection to which it is a guide is indeed, as Dr. Brezina remarks in the preface, a lasting monument to Felix Karrer, who has devoted much time and labour to the formation of this important part of the Vienna Museum. T. R. J.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—January 27, 1892.—Dr. W. T. Blanford, F.R.S., Vice-President, in the Chair.—The following communications were read:

1. "On the Hornblende-schists, Gneisses, and other Crystalline Rocks of Sark." By the Rev. Edwin Hill, M.A., F.G.S., and Prof. T. G. Bonney, D.Sc., F.R.S., V.P.G.S.

The authors refer to Mr. Hill's paper, published in 1887, for a general description of the Island. They were led to examine Sark again in the hope that its rocks might afford some clue to the genesis of the hornblende-schist of the Lizard. They describe the structure, macroscopic and microscopic, of the various foliated rocks. These are:—(*a*) The basement gneiss, a slightly foliated, somewhat granitoid rock, probably of igneous origin, but with some abnormal environment, and possibly intrusive into, instead of older than the rock which succeeds it. (*b*) The hornblende-schists, almost

[1] See Geol. Mag. April, 1889, pp. 174–177, for a notice of Chevalier Jervis's work on the "Economic Geology of Italy," treating of Italian materials of construction, ancient and modern, with numerous illustrations of public buildings.

identical with those of the Lizard, but in one case yet more distinctly banded. (*c*) Banded gneisses sometimes rather fine-grained, variably banded: quartzofelspathic layers alternating with those rich in biotite or occasionally hornblende. Some of these gneisses resemble the "granulitic group" of the Lizard; others recall certain of the less coarse, well-banded gneisses of Scotland, *e.g.* south of Aberdeen. Sometimes they are much "gnarled" by subsequent earth-movements, by which, however, as a rule, the crystalline rocks of the Island do not appear to have been very seriously affected. (*d*) A very remarkable group of local occurrence which exhibits great variety. In some places large masses of a dark green hornblende-rock are broken up and traversed by a pale red vein-granite or aplite. The former rock is drawn out into irregular lenticles, elongated lumps, and finally streaks, and has been melted down locally into the aplite. This then becomes a well-banded biotite gneiss, which macroscopically and microscopically agrees with types which are common among the Archæan rocks. Sark therefore presents an example of the genesis of such a gneiss, and the authors are of opinion that probably all the above-named rocks are of igneous origin, but became solid ultimately under somewhat abnormal conditions, to which the peculiar structures (which distinguish them from ordinary igneous rocks) are due. They attribute the banding to the effect of fluxional movements, anterior to final consolidation, in a mass to some extent heterogeneous. This hypothesis they consider may be applied to all gneisses or schists which exhibit similar structures—that is, to a considerable number (but by no means all) of the Archæan rocks.

The second part of the paper consists of notes on some of the dykes and obviously intrusive igneous rocks of the Island. Among these are four (new) dykes of "mica-trap," one of which exhibits a very remarkable "pisolitic" structure. The variety of picrite described by Prof. Bonney in 1889 (from a boulder in Port du Moulin) has also been discovered *in sitû*.

2. "On the Plutonic Rocks of Garabal Hill and Meall Breac." By J. R. Dakyns, Esq., M.A., and J. J. H. Teall, Esq., M.A., F.R.S., F.G.S. (Communicated by permission of the Director-General of the Geological Survey.)

The plutonic rocks described occur in a complex forming a belt of high ground S.W. of Inverarnan. They vary considerably in composition, and though gradual passages are sometimes found between more or less acid rocks, at other times the junction is sharp. The more acid are always found to cut through the less acid when the two rocks are found in juxtaposition, and fragments occurring in a rock are less acid than the rock itself. Though thus shown to be of different ages, they must evidently refer to one geological period. The first rocks to be formed were peridotites; then followed diorite, tonalite, granite, and eurite in order of increasing acidity.

The specific gravities, colours, and textures of the rocks are considered, and a detailed account of the constituent minerals given.

The essential minerals are arranged in the following order, based on their general distribution in the different type of rock:—Olivine, pyroxene, hornblende, biotite, plagioclase, orthoclase and quartz, microcline. The following is the order in which the principal constituents commence to form in the rocks:—Iron-ores, olivine, pyroxene, hornblende, biotite, plagioclase, orthoclase, microcline, and quartz. The chemical composition of the rocks is discussed, data being furnished by a series of analyses made by Mr. J. H. Player, and a diagrammatic representation of the molecular relations of the different bases and silica is given. The relations between mineralogical composition, chemical composition, and geological age are then considered; and the following conclusions are reached:—

(1) That the various rocks have resulted from the differentiation of the originally homogeneous magma.
(2) That the chronological sequence from peridotite to eurite is connected with the order of formation of minerals in igneous magmas.

3. "North Italian Bryozoa.—Part II. Cyclostomata." By Arthur William Waters, Esq., F.G.S.

The Chilostomata from the same localities were dealt with in volume xlvii. of the "Quarterly Journal." In the present paper a number of Cyclostomata are described, amongst the most interesting being a new species termed by the author *Diastopora brendolensis*, which has tubules similar to those of *D. obelia*. These are the only species in which tubules are known, and two modes of growth of the fossil seem to show that those who united under *Diastopora* erect and incrusting forms were right.

The ovicell by the side of the zoarium of *Hornera serrata*, described in the paper, is in a position new for the Cyclostomata.

II.—Feb. 10, 1892.—Sir Archibald Geikie, D.Sc., LL.D., F.R.S., President, in the Chair.—The following communications were read:

1. "The Raised Beaches, and 'Head' or Rubble Drift of the South of England: their relation to the Valley Drifts and to the Glacial Period; and on a late Post-Glacial Submergence.—Part I." By Joseph Prestwich, D.C.L., F.R.S., F.G.S.

The author remarks that, besides the subaerial, fluviatile, and marine Drifts of the South of England, there is another Drift which is yet unplaced. This he considers to be connected with the 'Head' overlying the Raised Beaches. Of these he describes the distribution, characters, and relations along the South Coast. The 'Head' overlies the beaches, and frequently overlaps them. In the beaches large boulders are found, and marine shells, of which lists for the various localities are given. The 'Head' frequently shows rough stratification of finer and coarser materials. It contains *mammalian bones, land-shells* only, and occasionally flint implements. On the coasts of Devon and Cornwall it is separated from the Raised Beaches by old sand-dunes.

In South Wales the beach occurs below the mammaliferous cave-

deposits, whilst material corresponding to the 'Head' seals up the cave-mouths. The ossiferous breccias of the caves are therefore intermediate in age between the beaches and the 'Head.'

The origin of the boulders is discussed, and it is inferred that they have been brought, not from the French coast, nor from a submerged land, but from a north-easterly source by floating ice through the Straits of Dover. The mollusca of the Raised Beaches, of which a list of 64 is given, are closely related to forms living in the neighbouring seas.

These Raised Beaches are not of the age of the Higher Valley-gravels; but the evidence (especially that yielded by the Somme Valley deposits) points rather to their connexion with the Lower Valley-gravels, and therefore, with the exception of the Caves, they represent the latest phase of the Glacial Period.

2. "The *Olenellus*-Zone in the North-West Highlands." By B. N. Peach, Esq., F.R.S.E., F.G.S., and J. Horne, Esq., F.R.S.E., F.G.S. (Communicated by permission of the Director-General of the Geological Survey.)

In the stratigraphical portion of this paper brief descriptions are given of certain sections in the Dundonnell Forest, from eight to ten miles N.N.E. of Loch Maree, which have yielded fragments of *Olenellus*. The organisms are embedded in dark-blue shales occurring near the top of the 'Fucoid Beds' and towards the base of the 'Serpulite Grit,' forming part of the belt of fossiliferous strata stretching continuously from Loch Eriboll to Strome Ferry—a distance of ninety miles.

In the Dundonnell Forest the basal quartzites rest with a marked unconformability on the Torridon Sandstone. There is an unbroken sequence in certain sections from the base of the quartzites either to the 'Serpulite Grit' or to the lowest bands of the Durness Limestone. At these horizons the strata are truncated by a powerful thrust, which, at Loch Nid, brings forward a slice of Archæan rocks with the Torridon Sandstone and basal quartzite.

The strata from the base of the quartzites to the base of the Durness Limestone, exposed in the Dundonnell Forest, are compared with their prolongations to the north and south of that region, from which it appears that there is a remarkable persistence of the various subzones identified in Assynt and at Loch Eriboll. But between Little Loch Broom and Loch Kishorn dark-blue shales near the top of the 'Fucoid Beds' have been observed at various localities, evidently occupying the same horizon as the *Olenellus*-shales in the Dundonnell Forest.

The Serpulites (*Salterella*) associated with the Trilobites in the 'Serpulite Grit' occur in the basal bands of the overlying limestone; they were found during last season in the brown dolomitic shales accompanying the *Olenellus*-shales in the 'Fucoid Beds,' and they were formerly detected in the third subzone of the 'pipe-rock' in Sutherland. Their appearance on these horizons leads us to cherish the hope that portions of *Olenellus* may yet be met with in certain shales in the quartzites and probably in the lowest group of limestone.

The evidence now adduced proves (1) that the 'Fucoid Beds' and 'Serpulite Grit' are of Lower Cambrian age, the underlying quartzites forming the sandy base of the system; (2) that the Torridon Sandstone, which is everywhere separated from the overlying quartzites by a marked unconformability, is pre-Cambrian.

The *Olenellus* which has been discovered is described as a new species (*O. Lapworthi*) closely allied to *O. Thompsoni*, Hall, from which it differs chiefly in the arrangement of the glabella-furrows and in the presence of a rudimentary mesial spine at the posterior margin of the carapace. Remains of other species referable to *Olenellus* are described, but these are too fragmentary for exact determination. All are characterized by a reticulate ornamentation similar to that described by Walcott in *O.* (*Mesonacis*) *asaphoides*, Emmons. The remains consist chiefly of portions of carapaces.

CORRESPONDENCE.

CONE-IN-CONE STRUCTURE.

SIR,—In the present February No. of the GEOLOGICAL MAGAZINE, Mr. A. C. G. Cameron in his paper on the "Kellaways Beds" makes reference to an indurated seam of sandy marl that exhibits Cone-in-cone Structure, and refers to an abstract in GEOL. MAG. of a paper of mine, that is printed in Trans. Geol. Soc. of Glasgow, in which I give an explanation of the above-mentioned structure. In this paper I am credited by Mr. Cameron with stating that in cone-in-cone structure, the apices of the cones point towards each other in the beds in which this structure is found. Had Mr. Cameron read the full text of my paper, he there would have seen that this statement was not mine, but was given in two of the quotations, illustrating some of the views formerly held by those that had written on cone-in-cone structure. Thus, H. C. Sorby, F.R.S., is quoted as having written—"The cones often occur in bands parallel to the stratification of the rock, their apices starting from a well-defined plane, and after extending upwards or downwards for a greater or less distance with their axis perpendicular to the plane of stratification, they end in bases parallel to it but not on the same level, some standing up above the general surface." The other quotation is from the Students' Manual of Geology, by Prof. J. B. Jukes, edited by Prof. A. Geikie, 1872. It is there stated that "some clay ironstones exhibit another concretionary form called 'cone-in-cone,' as the seam of ironstone breaks into conical forms, with the bases of the cones at the top and bottom of the seam, and their apices pointing inwards towards each other."

In my paper I have written against this statement, in both quotations, of the cones ever having their apices pointing inwards towards each other, and state, "I am inclined to think that such a description is due to faulty observation, or could only have been made from a badly preserved specimen, in which the structure was

obscure or much confused." I also further state, "that the apices are invariably turned to the under or lower side of the stratum, while their bases are as invariably directed to the upper surface."

In my explanation of cone-in-cone structure, I point out that it was probably due to a mechanical action, set up through chemical agencies, such as gases, that were generated by the decomposition of the organic matter present in the lower portion of the stratum, the elevatory power of such gases, as they escaped upwards to the surface of the bed, through the tube forming the central axis of each cone, brought up from below the successive layers of plastic mud, of which the cone structure is seen to be built up.

Hunterian Museum, University Glasgow, John Young.
February 13th, 1892.

READE'S THEORY OF MOUNTAIN BUILDING.

Sir,—In reply to Mr. Reade I am quite aware that he replied to Mr. Davison's argument last year, but in the opinion of good physicists that reply was no answer. Mr. Reade apparently failed to realize Mr. Davison's meaning, and the further explanation given in the postscript to my paper does not seem to have made it clearer to him.

My own ideas of the result of subsidence do not form the primary question in debate, which is—can we accept Mr. Reade's ideas? It is eminently desirable, therefore, that he should address himself to Mr. Davison's objection and postpone any consideration of my criticisms.

I am obliged to Mr. Reade for pointing out the error in my figures; an 0 has been omitted, but when supplied makes the case against him ten times worse than before. If I have misunderstood Mr. Reade's idea of expansive compression, or if my argument is unsound, I shall be glad to be corrected. A. J. Jukes-Browne.

Exeter, *Feb.* 10.

CONCERNING THE DIMENSIONS OF OLENELLUS.

Sir,—In his excellent paper "On *Olenellus Callavei*," in the Geol. Mag., Dec. 1891, p. 529, Professor C. Lapworth says: "The larger fragments collected indicate a length of about six inches and a breadth of about four inches. With the exception of *Olenellus* (*Holmia*) *Bröggeri*, Walcott, this form is the largest species of the genus yet discovered." Prof. Lapworth seems to have overlooked that *Olenellus* (*Holmia*) *Kjerulfi*, Linns., might reach fully the length of *O.* (*H.*) *Callavei*. In my paper "On *Olenellus Kjerulfi*," in Geolog. fören. förhandl. vol. ix. (1887) p. 512, I have stated that: "The largest specimen I have found has a breadth of 63 mm. between the eyes." The length of the body must, therefore, in this case, have been 155 mm., which is more than six inches.

Gerhard Holm.

OBITUARY.

THOMAS ROBERTS, M.A., F.G.S.,

ST. JOHN'S COLL., CAMB.; ASSISTANT TO THE WOODWARDIAN PROFESSOR.

BORN 1856. DIED JAN. 24TH, 1892.

MR. ROBERTS must have been a strong man to have come to the front as he did; for he had not the early advantages that the youths of our large towns generally have now in the way of lectures and schools and colleges, open to any boys who show a spark of intelligence.

His father was a contractor and agent in Wales, and at one time much better off than the ups and downs of the world left him in his old age. Tom Roberts was intended for the same line, and thus in early life was familiar with the construction of sea-walls, with laying railway lines, with building, and with the superintendence of quarries and mines.

Perhaps this influenced his choice of subjects in after-life. However that may be, he went to school, and showed such promise that he was encouraged and aided to pursue his studies in the University College of Wales at Aberystwith, where he obtained a scholarship for Mathematics. Here also he impressed his teachers with his power, and he was sent up to St. John's College, Cambridge, where he won a scholarship on entrance, and, being now able to throw himself entirely into the congenial study of Natural Science, at the end of his course he was placed in the First Class in the First Part of the Natural Sciences Tripos in 1882, and also in the First Class in the Second Part of the Natural Sciences Tripos in June, 1883.

In the spring of 1883 he was appointed Assistant to the Woodwardian Professor, in succession to Mr. E. B. Tawney, a post which he has held ever since.

It may be asked why a man of such knowledge did not do more original work, but the answer is easy. In the first place his time and energies were chiefly given up to educational work, and secondly he was preparing for a much larger undertaking, namely, a treatise on Palæontology, so that he had no time to keep himself before the public by frequent small descriptions or controversial papers. Moreover, such time as he had to spare was at everybody's disposal. His work must be listened for in echoes rolling on through other people's publications, and the record must be looked for, not in the Proceedings of Societies, but among the hundreds of students that have passed through the Woodwardian Museum since he first took his share in its management and in its educational work.

But if his published work was not voluminous, it was good. He was a stratigraphical palæontologist of a very high order, and those who had the good fortune to work with him in the field will remember how careful he always was to work out the fossils of each zone, and how he allowed no correlation which was not supported by palæontological evidence.

We pass quickly over the joint paper by Marr and Roberts on the

Lower Palæozoic Rocks of the neighbourhood of Haverfordwest,[1] because in that he was associated with the keenest stratigraphical palæontologist we have, on ground which he, rather than Roberts, has made peculiarly his own. Whatever Roberts's contribution to that work may have been, he must have come out of it a stronger man from the contact. But in his description of the Jurassic Rocks, we see in one paper after another first that careful working out of zones in one connected set of sections, and then suggested correlation of horizons between more or less widely separated areas.

He first undertook the examination of the Jurassic Rocks of the neighbourhood of Cambridge, upon which he wrote an essay, for which the Sedgwick Prize was awarded to him in 1886. It was hoped by his friends and by himself, that this essay would some day be expanded into a much larger work, or at any rate that its scope might be considerably extended. As it stands, it is a valuable contribution to the Life History of the Earth, and, for students of the geology of the neighbourhood of Cambridge, a useful handbook. The Syndics of the University Press have undertaken to publish it, and many friends have volunteered their services to help to see it through the press *in Memoriam*.

In the following year he read a paper before the Geological Society,[2] "On the Correlation of the Upper Jurassic Rocks of the Swiss Jura with those of England." This was the outcome of an excursion for which he received a grant from the Worts Fund in 1884. In it he gives a detailed description of the more important subdivisions above the horizon of our Kellaways Rock, with numerous sections, and full lists of fossils. He points out that the thick clays of Kimeridge and the variable beds of Portland and Purbeck are in the Jura all represented by massive limestones and that, as might be expected from such difference of sediment, there is a considerable difference in the fauna of the two areas, but that still some well-marked zones make an approximate correlation possible. The views of various authors and his own as to the identity of certain widely separated zones, he presents tabulated in parallel columns for easy reference, and explains wherein he differs from the continental geologists as to the synchronism or the grouping of the several deposits.

In 1888 the Lyell Fund was awarded to him in token of appreciation of these investigations. Having thus prepared himself for the recognition of the different horizons in the Jurassic Rocks, even when presenting very various aspects, he turned his attention to "the Upper Jurassic Clays of Lincolnshire,"[3] and traced through that district a zone which had not been previously recognized, and which he identified with certain clays in the neighbourhood of Cambridge, referred by him to the Corallian.

The thorough way in which he worked out a palæontological inquiry may be gathered from his early note[4] on what he considered a new species of *Conoceras* from Llanvirn. He described the

[1] Q.J.G.S. vol. xl. 1884, p. 476.
[2] Q.J.G.S. vol. xliii. 1887, p. 229.
[3] Q.J.G.S. vol. xlv. 1889, p. 545.
[4] Q.J.G.S. vol. xl. p. 636.

specimen and its state of preservation, pointing out sources of error arising from confounding superinduced structures in the rock, with original markings on the organism. He compared it with those species which appear most nearly to resemble it among previously described forms. He pointed out the exact geological horizon from which it was obtained, as determined by the associated fossils, and then gave the technical description of his new species.

The same treatment of the specimens and of the species is seen in his description [1] of "Two Abnormal Cretaceous Echinoids."

In Palæontology also we must look for his work not so much in published descriptions of new species, as in the large numbers of named fossils in the Woodwardian Museum, from almost every horizon, the determination of which we owe to him.

The characteristic of his work as of the man was its honesty. We who lived and worked with him up to a few days of the end feel his loss at once; he is no longer there to help, and many another coming up to the old Museum from time to time will feel it too; for when a friend or stranger asked to see something in our collections, we would say, "You will find Tom Roberts there," with full confidence that our visitor would return well pleased and the honour of our Museum would be well sustained.

He was a man of great force of character, of clearness of vision, and soundness of judgment. False reasoning rarely escaped him, and you could no more lose sight of his intellectual presence than of his large and powerful frame. Yet his gentle sympathetic manner and his open truthful eye gave you at once the comfortable feeling that you need not be on your guard with him. Students said that he never tried to put himself on a higher pedestal by scoring off them. He led them on, and rather than drive or urge them, he would ask them to help him to get them through with credit, as if he, not they, were most interested in their success.

T. McKenny Hughes.

FREDERICK DREW, F.G.S., F.R.G.S.

Born August 11, 1836. Died October 25, 1891.

Mr. Frederick Drew, F.G.S., F.R.G.S., was born August 11th, 1836, at Southampton, where his father kept a well-known private school, and at this school he was educated until he was seventeen years of age, when he entered the Royal School of Mines, at that time (1853) recently established in connexion with the Jermyn Street Museum. Here he distinguished himself, although younger than some of the other students, by taking all the prizes offered, including the Duke of Cornwall's Scholarship, a Royal Scholarship, and the Edward Forbes medal, the last two for the first year in which they were awarded.

In 1855, on leaving the School of Mines, Frederick Drew joined the Geological Survey of Great Britain, and remained on the staff till 1862, being chiefly engaged in the south-east of England. His

[1] Geol. Mag. Vol. VIII, 1891, p. 116.

principal contributions to science during these seven years included an important paper on the Hastings Sands, published in the Quart. Journ. Geol. Soc. for 1861, and an account of the Geology of Folkestone, Rye, and Romney Marsh, which appeared in the Geological Survey Memoirs. The subdivisions of the Hastings Sands proposed by Drew have been accepted by the Survey and by British geologists generally, and he introduced some modifications of much value in the classification of the Lower Cretaceous beds throughout the Wealden area.

In 1862 the Maharaja of Kashmir desired to have the services of a geologist to report on the mining wealth of his country, and the appointment was accepted by Drew, who remained for ten years in Kashmir. At first he was, nominally, engaged in mining research; naturally the ideas of an Indian Maharaja and those of a European geologist as to the methods and objects of such inquiries would differ materially, and it is not only highly creditable to Drew, but rather remarkable that, despite the inherent difficulties of his position, he should have impressed the Maharaja and his advisers so favourably as to be appointed first to the governorship of Jummu, and subsequently to the still more important one of Ladák. There can be no question that his skill and tact in dealing with natives of India, and his even temper and coolness in emergency, led to his being entrusted with the important posts that he filled.

The principal results of his residence in Kashmir, and of the exceptional opportunities he enjoyed for seeing the country and its inhabitants, were communicated to the public in his well-known work on Jummu and Kashmir, published in 1875.[1] The greater part of his geological observations were necessarily reported to the Kashmir Government alone, but some purely scientific notes on the alluvial deposits that occupy so enormous an area in the Upper Indus Basin, as in other parts of Central Asia, were communicated by him to the Geological Society.[2] A large portion of this paper is an account of the physical geography of the country, and describes the land contours and their mode of origin in Ladák and other parts of Kashmir territory, whilst the work on Jummu and Kashmir is a storehouse of geographical and ethnological data, of which later writers have frequently had occasion to avail themselves. The work is well written and extremely interesting. An abridged edition was published by the author in 1877, under the title of "Northern Barrier of India."

The only communication to the publications of the Royal Geographical Society that appeared from Drew's pen was his description, in a letter to Sir Roderick Murchison, of the steps taken, under instructions from the Maharaja of Kashmir, to ascertain the circumstances attending the murder of Mr. Hayward, the well-known explorer of the countries lying north of Kashmir. Mr. Hayward,

[1] The Jummo and Kashmir Territories, a Geographical Account. By Frederick Drew, F.G.S., F.R.G.S., Assoc.R.S.M. London, 1875. 8vo. pp. xvi. and 568. 8 folding maps and sections, and 34 illustrations.

[2] Quart. Journ. Geol. Soc. vol. xxix. 1873, pp. 441-471.